CHAPTER 14

Groundwater

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

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14. Groundwater

14.1 Scope of chapter

This chapter includes a description of the groundwater existing environment, environmental values, and impact assessment of the Inland Rail North Star to NSW/Queensland Border project (the proposal) on groundwater resources. The groundwater chapter summarises key aspects of the groundwater impact assessment with full details of the assessment provided in Appendix N: Groundwater Technical Report.

The existing environment is described and the potential impacts of the proposal are assessed. Potential short- and long-term impacts on local and regional groundwater resources have been assessed for the proposal's construction and operation phases. The results of the impact assessment and recommended mitigation measures are outlined.

14.1.1 Secretary's Environmental Assessment Requirements

This chapter has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) as shown in Table 14.1.

TABLE 14.1 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS COMPLIANCE

	Item 9: Water—Hydrology
Desired performance outcome	Long-term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.
Current guideline	*Biodiversity Assessment Method Operational Manual—Stage 1* (OEH, 2018) *Managing Urban Stormwater: Soils and Construction—Volume 1* (Landcom, 2004) and *Managing Urban Stormwater: Soils and Construction—Volume 2* (A. Installation of Services; B. Waste Landfills; C. Unsealed Roads; D. Main Roads; E. Mines and Quarries) (DECC, 2008) *NSW Aquifer Interference Policy* (DPI, 2012a) *NSW Sustainable Design Guidelines Version 4.0* (TfNSW, 2017) *Risk Assessment Guidelines for Groundwater Dependent Ecosystems: Volume 1—the conceptual framework* (Office of Water, 2012)

SEARs requirement	EIS section
Item 9.1 The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the BAM.	Sections 14.4, 14.4.9.3 and 14.7
Item 9.2 The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration, sources, security and licensing requirements.	Section 14.6
Item 9.3 The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	
a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	Sections 14.4, 14.4.9.3, 14.6 Section 14.7
b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Sections 14.7 and 14.8

SEARs requirement	EIS section
c) changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Sections 14.7 and 14.8
d) direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Chapter 13: Surface Water and Hydrology
e) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Sections 14.7 and 14.8
f) water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Section 14.7
Item 9.4 The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Section 14.8.3

Desired performance outcome	Item 10: Water–Quality The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable).
Current guideline	*NSW Water Quality and River Flow Objectives* at environment.nsw.gov.au/ieo/ Using the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZ Guidelines) (Australian and New Zealand Governments and Australian state and territory governments, 2018) and *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (DEC, 2006) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000) *Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (DEC, 2008) *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom, 2004) and *Managing Urban Stormwater: Soils and Construction Volume 2* (A. Installation of Services; B. Waste Landfills; C. Unsealed Roads; D. Main Roads; E. Mines and Quarries) (DECC, 2008)

SEARs requirement	EIS section
Item 10.1 The Proponent must:	
a) state the ambient NSW Water Quality Objectives (WQOs) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	Section 14.4.9
b) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Sections 14.7.2.6 and 14.7.3
c) identify the rainfall event that the water quality protection measures will be designed to cope with;	Chapter 13: Surface Water and Hydrology
d) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	Section 14.9
e) demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: ▸ where the NSW WQOs for receiving waters are currently being met, they will continue to be protected; and ▸ where the NSW WQOs are not currently being met, activities will work toward their achievement over time;	Sections 14.7 and 14.8

SEARs requirement	EIS section
f) justify, if required, why the WQO cannot be maintained or achieved over time;	Section 14.4.9.3
g) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Section 14.8
h) identify sensitive receiving environments (which may include marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments; and	Sections 14.4.7, 14.4.8 and 14.8
i) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Section 14.8.3 Appendix N: Groundwater Technical Report (Groundwater Monitoring Program)

The description and assessment of groundwater resources are summarised in this groundwater chapter and detailed in Appendix N: Groundwater Technical Report.

14.2 Legislation, policies, standards and guidelines

This EIS chapter has been prepared with consideration to key legislation, policies, standards and guidelines from the Commonwealth of Australia and the State of New South Wales (NSW). The legislation, policies and guidelines relevant to the proposal with respect to groundwater are presented in Table 14.2.

TABLE 14.2 SUMMARY OF LEGISLATION, POLICIES, STRATEGIES OR GUIDELINES

Legislation, policy, strategy or guideline	Relevance to the proposal
Commonwealth	
Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act)	The EPBC Act is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect, manage and regulate nationally and internationally important environmental assets, defined in the EPBC Act as matters of national environmental significance (MNES). This Act includes the regulation of activities that may impact on Commonwealth land. The Department of the Environment and Energy (DoEE), who are responsible for administering the EPBC Act, has determined that the proposal does not have the potential for significant impacts on water resources.
State (NSW)	

Protection of the Environment Operations Act 1997 (NSW)	The Act is the central piece of environment protection legislation overseen by the EPA. Key features of this legislation include:
	- Protection of the environment policies (PEPs)
	- Environment protection licensing
	- Regulation of scheduled and non-scheduled activities:
	  - The NSW EPA is the regulatory authority for scheduled activities (activities declared under Schedule 1 of the Act)
	  - The NSW EPA is also the regulatory authority for non-scheduled activities, where activities are undertaken by a public authority.
	The proposal will be a scheduled activity (railway systems activities under Schedule 1) during construction and an environment protection licence would be required for this activity.

Legislation, policy, strategy or guideline	Relevance to the proposal

Water Management Act 2000 (NSW)	The Act provides a framework for sustainable and integrated water management across NSW. The key objectives are as follows:
	▸ To apply the principles of ecologically sustainable development
	▸ To protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity, and their water quality
	▸ To recognise and foster the significant social and economic benefits to the state that result from the sustainable and efficient use of water, including:
	  ▸ Benefits to the environment
	  ▸ Benefits to urban communities, agriculture, fisheries, industry and recreation
	  ▸ Benefits to culture and heritage
	  ▸ Benefits to Aboriginal People in relation to their spiritual, social, customary and economic use of land and water.
	▸ To recognise the role of the community, as a partner with government, in resolving issues relating to the management of water sources
	▸ To provide for the orderly, efficient and equitable sharing of water from water sources
	▸ To integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna
	▸ To encourage the sharing of responsibility for the sustainable and efficient use of water between the government and water users
	▸ To encourage best practice in the management and use of water.
	The main instruments applied to meet these objectives are the *Water Management (General) Regulation 2018*, Water Sharing Plans and the *NSW Aquifer Interference Policy,* which are discussed further in this table.
	While the proposal is approved as a state-significant infrastructure project, and several approvals are not required (refer Chapter 5: Planning and Assessment Process) an aquifer interference approval (refer NSW Aquifer Interference Policy below) is not exempt.

Water Act 1912 (NSW)	The Act is gradually being phased out across NSW and replaced by the *Water Management Act 2000* (NSW). The *Water Act 1912* is relevant where an activity leads to a take from a groundwater or surface water source not currently covered by a Water Sharing Plan. As Water Sharing Plans already apply to the proposal site, the *Water Act 1912* does not apply.
Water Management (General) Regulation 2018	This regulation details procedural, technical and licensing requirements under the *Water Management Act 2000* (NSW), as well as the functions and powers of water supply authorities.
Water Sharing Plans	After the *Water Management Act 2000* (NSW) was introduced, Water Sharing Plans have become the basis for equitable sharing of surface water and groundwater between water users. Most of NSW is covered by Water Sharing Plans. Where an activity leads to a take from a groundwater or surface water source covered by a Water Sharing Plan, an approval and/or licence is required. Typically, the Act requires: ▸ A water access licence to take water ▸ A water supply works approval to construct a work ▸ A water use approval to use the water. There are three Water Sharing Plans relevant to groundwater for the proposal, which are discussed below.
Water Sharing Plan: NSW Border Rivers Unregulated and Alluvial Water Sources (Department of Primary Industries (DPI), 2012b)	This Water Sharing Plan is applicable to 13 surface water and 4 alluvial groundwater sources combined within the same plan due to the highly connected nature of these systems (DPI, 2012b). Alluvial water sources under this plan include the NSW Border Rivers—Downstream Keetah Bridge Alluvial Water Source associated with Quaternary alluvium from the Macintyre–Dumaresq River system. This alluvial source underlies the proposal at the northern portion of the alignment from approximately Ch 25 km towards the NSW/QLD border. From approximately Ch 25 km down to North Star, shallow groundwater is associated with the Croppa Creek and Whalan Creek surface water source and related alluvium. Due to the shallow nature of these alluvial systems, this Water Sharing Plan is considered the most significant for the proposal activities.

<table>
<tr><th>Legislation, policy, strategy or guideline</th><th>Relevance to the proposal</th></tr>
<tr><td>Water Sharing Plan: NSW Border Rivers Regulated River Water Source (DWE, 2009b)</td><td>This plan applies to all regulated river sections in the NSW Border Rivers Water Management Area (NSW DWE, 2009a), which includes the section of the Macintyre River at the NSW/QLD border in the northern section of the proposal.</td></tr>
<tr><td>Water Sharing Plan: NSW Great Artesian Basin Groundwater Sources (Department of Water and Energy (DWE), 2009)</td><td>This plan applies to sandstone aquifers of the Great Artesian Basin and includes five identified water sources.

The proposal site lies within the Eastern Recharge Groundwater Source, which represents a region of groundwater recharge to the Great Artesian Basin via an outcrop of the Pilliga Sandstone and overlying strata (DWE, 2009b). This Water Sharing Plan sets long-term annual average extraction limits for this groundwater source developed for high-volume irrigation in areas enveloping the proposal.

A large number of registered bores have been identified within 10 km of the proposal site. The registered bores within and adjacent to the proposal site intersect fractured rock aquifers related to the Pilliga Sandstone groundwater source (aquifer). This aquifer is typically encountered between 40 m and 200 m below ground level (mbgl) in this area. Given the depth of this water source (>40 mbgl), it is considered less significant to the proposal activities.</td></tr>
<tr><td>NSW Aquifer Interference Policy (DPI, 2012a)</td><td>The policy includes requirements for the evaluation of aquifer interference activities administered under the Water Management Act 2000 (NSW). The main components to this policy are:
All water taken must be properly accounted for
Activities must address minimal impact considerations for impacts on the water table, water pressure and water quality
Planning must be undertaken for measures in the event that the actual impacts are greater than predicted, including ensuring sufficient monitoring is in place.
The policy is consistent with the groundwater assessment.</td></tr>
<tr><td>Sustainable Design Guidelines Version 4.0 (Transport for NSW (TfNSW), 2017)</td><td>The guidelines aim to achieve sustainable development practices through the application of sustainability initiatives into the design and construction of transport infrastructure projects.

The primary aims of the guidelines include:
Ensuring the development, expansion and management of the transport network is sustainable and resilient to climate change
Minimising the impacts of transport on the environment, encompassing transport operations, infrastructure delivery and maintenance and corporate activities.</td></tr>
<tr><td>NSW State Groundwater Dependent Ecosystems Policy (Department of Land and Water Conservation (DLWC), 2002)</td><td>The policy relates to the management of groundwater dependent ecosystems (GDEs) in NSW and includes the following key principles:
The scientific, ecological, aesthetic and economic values of GDEs, and how threats to them may be avoided, should be identified, and action taken to ensure the most vulnerable and most valuable ecosystems are protected
Groundwater extraction should be managed within the sustainable yield of aquifer systems, so that the ecological processes and the biodiversity of dependent ecosystems are maintained and/or restored. Management may include setting threshold levels critical for ecosystem health, and controls on extraction near GDEs.
Priority should be given to ensuring that sufficient groundwater of suitable quality is available when needed for:
Maintaining ecosystems that are known to be, or are likely to be, groundwater dependent
GDEs that are under an immediate or high degree of threat from groundwater-related activities.
The groundwater assessment is generally consistent with the policy.</td></tr>
</table>

14.3 Methodology

14.3.1 Study area

The groundwater study area for the purpose of this chapter is defined as an area within a 1 km radius of the centre line of the proposal site. Where there is a paucity of available groundwater data, such as limited registered bore data, the search radius has been increased beyond the 1 km study area (i.e. up to 10 km). Potential borrow pits located up to 18 km from the proposal centre line have also been evaluated as part of this groundwater impact assessment. The location of the proposal and key features are in Figure 14.1.

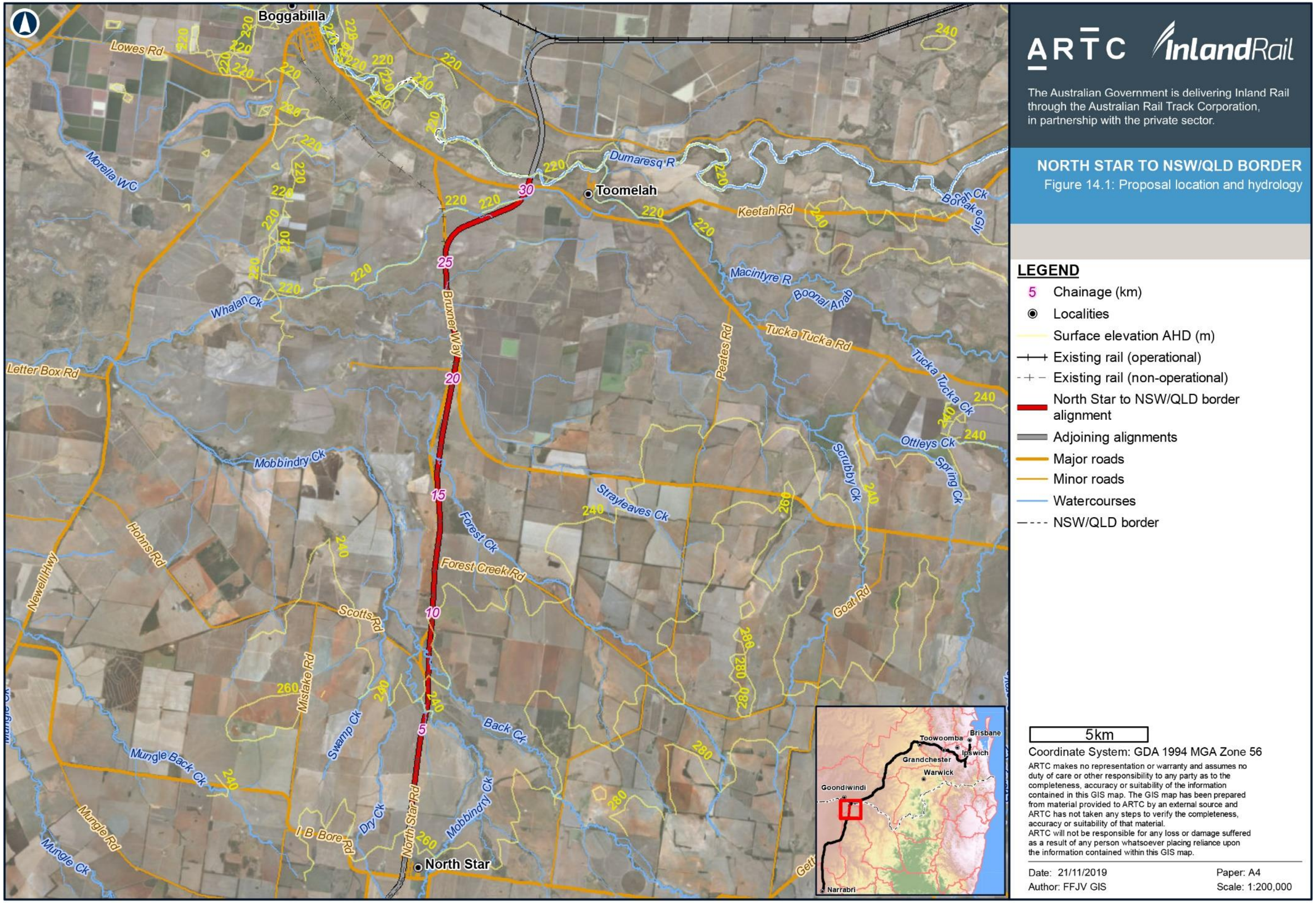
14.3.2 Assessment methodology

A standardised approach to the groundwater qualitative significance assessment has been adopted.

Following the identification and assessment of baseline environmental values, the potential impacts of the proposal are described and assessed, and mitigation measures prescribed.

The sensitivity of the environmental value and the magnitude of the potential impacts are the key elements considered to determine significance. These aspects were assessed using a significance matrix allowing for the determination of the appropriate significance classifications, as detailed in Table 14.3.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: NCW Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_ARTC_Fig14.1_Location_Hydrology_Rev1.mxd Date: 31/01/2020 14:45

TABLE 14.3 CLASSIFICATIONS ADOPTED FOR THE SIGNIFICANCE ASSESSMENT

Significance	Description
Major	Arises when an impact will potentially cause irreversible or widespread harm to an environmental value that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.
High	Occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of the environmental value. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred to preserve its intactness or conservation status.
Moderate	Results in degradation of the environmental value due to the scale of the impact or its susceptibility to further change even though it may be reasonably resilient to change. The abundance of the environmental value ensures it is adequately represented in the region, and that replacement, if required, is achievable.
Low	Occurs where an environmental value is of local importance and temporary or transient changes will not adversely affect its viability, provided standard environmental management controls are implemented.
Negligible	Does not result in any noticeable change and, therefore, the proposed activities will have negligible effect on environmental values. This typically occurs where the activities are located in already disturbed areas.

14.3.3 Staged assessment approach

To achieve the study scope and objectives outlined in the SEARs, the groundwater significance assessment comprises two components: a description of the existing hydrogeological environment and an assessment of the impacts of the proposal on that environment. To meet the requirements, the groundwater assessment undertook a staged approach to ensure the correct scientific development of the groundwater study:

- Stage 1—Desktop review and site investigations: Publicly available groundwater datasets and geological reports were reviewed to characterise baseline groundwater conditions, to identify relevant groundwater environmental values, to determine existing groundwater uses and to develop a conceptual groundwater model.

  Groundwater investigations were completed during the period July to October 2018 concurrently with geotechnical investigations. This site-specific groundwater data was used to further refine and describe the baseline conditions and the conceptual hydrogeological model.

- Stage 2—Potential groundwater impacts and significance assessment: Potential short- and long-term impacts on groundwater (both local and regional) resources were assessed based on a review of the proposed rail alignment design (construction and operation) and the existing hydrogeological regime identified in Stage 1. This approach considers the sensitivity (or vulnerability) of an environmental value and the magnitude of the impact to develop a significance rating.
- Stage 3—Report preparation: The groundwater technical study report was prepared (Appendix N: Groundwater Technical Report), which contains baseline groundwater data, a conceptual hydrogeological model, assessment of potential groundwater impacts, the results of the significance assessment and recommended mitigation measures.

  The key outcomes of Appendix N: Groundwater Technical Report were used to compile this chapter.

14.3.4 Data sources

Data used in this assessment is based on a review of publicly available information and an ongoing geotechnical assessment for the proposal. Regional- (catchment) scale studies have also been reviewed to describe the existing groundwater resources and allow for the assessment of the proposal on the current groundwater regime. While there are ongoing investigations, these reports are not held within the public domain but have informed various aspects of the proposal to allow for an accurate understanding of the existing environment and, in turn, this accuracy is incorporated into the significance assessment for development of specific mitigation and management measures for identified potential impacts.

The description of the existing hydrogeological regime within the study area and the groundwater impact assessment is based on the following information sources (refer Table 14.4):

TABLE 14.4 DATA SOURCES FOR THE GROUNDWATER STUDY

Data	Source
Hydrology/ climate	Historical Climate Database—Bureau of Meteorology (BoM) Appendix G: Surface Water Quality
Soil types	*Inland Rail: Phase 2—North Star to Border: Geotechnical Report—Factual* (ARTC, May 2019)
Geology	*Inland Rail: Phase 2—North Star to Border: Geotechnical Report—Factual* (ARTC, May 2019) Stratotectonic Map of New South Wales 1:1 000 000—1997 (Scheibner, 1997) Goondiwindi 1:250,000 Geological Sheet—1973 (Senior, 1973) *Toenda-1 Well Completion Report* (Orion Petroleum Ltd, 2010) Queensland Registered Bores Online Database (Department of Natural Resources and Mines (DNRM, 2019) NSW Registered Bores Online Database (NSW Office of Water)
Groundwater levels and quality	NSW Registered Bores Online Database (NSW Office of Water) Queensland Registered Bores Online Database (DNRM) *Inland Rail: Phase 2—North Star to Border: Geotechnical Report—Factual* (ARTC, 2019) *Inland Rail—Section 270 (North Star to Border) 100% Feasibility Design Scope of Works: Hydrogeology* (ARTC, 2019b)
GDEs	*Groundwater Dependent Ecosystems Atlas* (GDE Atlas) (Bureau of Meteorology (BoM), 2018a) (bom.gov.au/water/groundwater/gde/map.shtml)
Groundwater use and management	*Gwydir Subregion—Bioregional Assessment Program* (Australian Government, 2018) Water Sharing Plans (NSW DPI and DWE, various dates) Queensland Globe—Water Management Datasets (qldglobe.information.qld.gov.au/)

14.4 Existing environment

This section describes the existing hydrogeological regime and is based on a review of available hydrogeological reports, site investigations between July to October 2018, and state government data sets in Table 14.4. The following section refers to groundwater bores shown on Figure 14.2.

There are two main aquifer systems considered relevant to the proposal site:

- Cenozoic alluvium deposits associated with the Border Rivers Alluvium and other drainage systems crossed by the alignment (i.e. Macintyre River, Whalan Creek and Mobbindry Creek). Strayleaves Creek is a surface water feature of interest for the proposal (located south of the proposal) and is considered an offshoot of Whalan Creek; therefore, for the purposes of this study, Whalan Creek is considered to include Strayleaves Creek.
- Jurassic to Cretaceous sedimentary rocks of the Surat Basin that form part of the hydrogeological Great Artesian Basin (GAB) units' Kumbarilla Beds and the Walloon Coal Measures.

These aquifers have potential to be sensitive to possible groundwater-affecting activities associated with the proposal.

The following sections describe these aquifers in the context of the hydrogeological regime of the groundwater study area.

14.4.1 Existing hydrogeological understanding

14.4.1.1 Cenozoic Alluvium

Occurrence

Cenozoic-aged alluvial aquifers are the uppermost (shallow) aquifers within the proposal site and are mapped in association with the current major watercourses (e.g. Macintyre River and Whalan Creek) and antecedent systems that form paleovalley fill and broad alluvial fan systems within and surrounding the proposal.

This aquifer forms the 'NSW Border Rivers—Downstream Keetah Bridge' Alluvial Water Source (DPI, 2012b). Other areas of mapped alluvium include narrower units within Mobbindry Creek and Whalan Creek. Subdivision of the alluvium into a shallow Narrabri Formation and deeper Gunnedah Formation is often applied to the alluvium in the Border Rivers region and is summarised in Table 14.5.

TABLE 14.5 SUMMARY OF LITHOSTRATIGRAPHY FOR THE GROUNDWATER STUDY AREA (EXON, 1976 AND RANSLEY ET AL., 2015)

Alluvial unit	Stratigraphic position	Lithology	Thickness	Aquifer properties
Narrabri Formation	Upper-most unit, forms ground surface in river valleys	Sands, gravels and silts	10 m to 30 m	Unconfined aquifer, recharge from stream loss, rainfall and excess irrigation.
Undifferentiated Clay	Separates Narrabri and Gunnedah formations	Clay	2 to 15 m	Low permeability
Gunnedah Formation	Overlies Surat Basin strata	Sands, gravels and clays. Fines upwards into clays.	Up to 70 m	Semi-confined, recharge from cross formational flow, vertical leakage from underlying aquifers, rainfall /runoff.

Based on a review of registered bore lithological descriptions for the alluvium in the northern portion of the proposal, the water-bearing zone is typically composed of sand or sandy gravels overlain by a fine-grained unit of clay, silt and clayey sands that may result in localised semi-confined conditions. This overlying fine-grained unit extends from the surface to 5–10 mbgl and was intersected in most site-investigation boreholes between the Macintyre River and Whalan Creek (Ch 20 km to Ch 30 km). The inferred depth to the top of the water-bearing zone within the alluvium is presented in Table 14.6 and is based on a review of registered bores and site-investigation boreholes.

TABLE 14.6 SUMMARY OF ALLUVIUM CHARACTERISTICS AND DEPTH TO THE WATER BEARING ZONE ALONG THE PROPOSAL ALIGNMENT

Chainage	Description	Inferred depth to top of water bearing zone	Comments
Ch 0 km to Ch 5.7 km	Thin soils, alluvium and residual clays overlying Surat Basin strata	No water observed in alluvial sediments or residual soils in registered bores (no site-investigation boreholes in this area). Possible shallow-perched groundwater in soils/sediments overlying clay.	Thin alluvium/colluvium (0–9 m) inferred from registered bores: GW005170 (clays 0–9.1 mbgl) and GW901938 (clays 0–29 mbgl)
Ch 5.7 km	Alluvium at Mobbindry Creek	No water observed in site-investigation borehole BH2201 or registered bores in proximity (refer next column)	Alluvial sediments inferred, from 4–10 mbgl as highly variable, from registered bores GW967837, GW967836, GW967835 and site-investigation bore BH2201 installed within the Mobbindry Creek Alluvium
Ch 8.1 km	Alluvium at Back Creek crossing	No water observed in site-investigation borehole BH2202 or registered bores in proximity (refer next column)	Alluvial sediments inferred, from 4–10 mbgl as highly variable, from registered bores GW967837, GW967836, GW967835 and site-investigation bore BH2202 installed within the Back Creek Alluvium

Chainage	Description	Inferred depth to top of water bearing zone	Comments
Ch 8.1 km to Ch 20.0 km	Thin soils, alluvium and residual clays overlying Surat Basin strata	No water observed in alluvial sediments or residual soils in registered bores in proximity (refer next column) or site-investigation borehole BH2203	GW018995 (0–3 m soil, 3.0– 19.2 m clays, top of shale at 19.2 mbgl) GW004689 (0–1.0 soils, 1.0– 33.22 mbgl clay)
Ch 20.0 km to Ch 29.6 km	Alluvium from Whalan–Macintyre fluvial systems. Sands and sandy gravels.	Typically, the water-bearing zone is located from 6.0–10 mbgl (refer next column for bores, registered and site-investigation bores).	Based on registered bores GW036694, GW036693, GW027891, GW027893, GW027892 and site-investigation bores BH2204, BH2206, BH2207, BH2208, BH2212, BH2214
Ch 29.6 km to Ch 30 km	Macintyre River Alluvium. Sands and sandy gravels	Typically, the water-bearing zone is located from 10–15 mbgl (refer next column for bores, registered and site-investigation bores). The reported water-bearing zone is dominantly sandy gravels overlain by clays and sandy clays.	Based on registered bores GW022001, GW005224, 77498A, 77390, GW030585, GW030590, GW039280 and site-investigation bores BH2213, BH2215, BH2216, BH2217, BH2218

Regional groundwater recharge, discharge and flow

Groundwater flow in the alluvial aquifers is considered to mimic topography and is limited by the distribution of alluvial sediments in the region (i.e. between Ch 20 km to Ch 30 km and more localised in creeks further south). To assess groundwater levels spatially, the depths to water from each bore are converted to elevation (metres above the Australian Height Datum (mAHD)) to account for topographic relief and allow for comparison to other datasets. Figure 14.1 depicts the surface topography across the groundwater study area and ranges from approximately 260 mAHD near North Star to approximately 220 mAHD in the north, near the Macintyre River. Regional mapping indicates a general north to northwest flow of groundwater in the shallow alluvial aquifer across the study area. Groundwater elevations resultant from site-investigation bores in October 2018 ranged from 213–218 mAHD, which are generally consistent with the regional flow gradients and the distribution of alluvium.

Locally, groundwater flow within the alluvial sediments is expected to be towards the perennial Macintyre River, particularly between Ch 20 km and Ch 30 km. This is due to the alluvial aquifers being influenced by, and hydraulically connected to, surface water features. Such relationship of surface-water–groundwater interaction and strong hydraulic connection is demonstrated by the responses of the water levels in several monitored bores near the proposal site during periods of high/heavy rainfall. Groundwater level responses to flooding events, e.g. example those that occurred in January 1996 and July 1998, are clearly depicted when hydrographs are compiled for monitored bores within the alluvium adjacent to the Macintyre River. Groundwater elevations rose up to 1 m from typical levels (refer bore hydrographs 41640005-B, GW36684, and GW036693 in Appendix N: Groundwater Technical Report).

Recharge to the alluvial aquifers is expected to occur via the following primary mechanisms:

- Recharge from stream losses from the regulated Dumaresq and Macintyre rivers
- Recharge from stream losses during seasonal flow in minor creeks/tributaries (i.e. Mobbindry Creek)
- Direct infiltration from rainfall and irrigation where permeable alluvial sediments are exposed
- Upward leakage from underlying Surat Basin strata (CSIRO, 2007).

Groundwater discharge mechanisms predominantly include throughflow/baseflow to the alluvial sediments of surface water features in times of low rainfall/stream flow and vertical migration to the underlying strata, where basal alluvial clays are limited in thickness, lateral extent, and are appropriately permeable where a downward vertical gradient is present, e.g. during high rainfall and/or flow events.

Limited effective storage in the coarser-grained permeable alluvial sediments is likely to result in groundwater level decline due to discharge via baseflow in this aquifer system. Such groundwater level decline is pronounced during the dry season in areas outside of the influence of artificial recharge from the regulated Dumaresq and Macintyre rivers via baseflow/throughflow.

Alluvial sediments within the ephemeral creek systems (i.e. Mobbindry and Forrest creeks) generally do not maintain sustainable groundwater resources due to the nature of such temporary systems. Groundwater within the alluvial aquifers associated with ephemeral creek systems can act as recharge to surface water features when dry but also migrates vertically into (as discharge from alluvium) the underlying sedimentary units (as recharge to these underlying units) and/or down hydraulic gradient due to low effective storage.

Hydraulic properties

Interrogation of the available databases did not result in hydraulic aquifer test results for the alluvial aquifers within the groundwater study area.

The NSW DPI estimates bore yields of up to 4.5 litres per second (L/s) for the NSW Border Rivers—Downstream Keetah Bridge Alluvial Water Source.

Bore yields from available registered bore data indicate a wide range of values: from 0.2–3.8 L/s. This range indicates high heterogeneity within the alluvial aquifers (fining upward and downward sequences) where yields are related to the extent and thickness of the coarser-grained alluvium.

Slug tests were completed at six monitoring bores installed within the alluvial aquifers during the 2018 site investigations (Appendix N: Groundwater Technical Report); of these six tests, five were able to be analysed (one location did not recover sufficiently for analysis). Resultant hydraulic conductivity (K) values were typically 0.2 to 0.8 m/day, which are considered lower than literature values for clayey sands and clayey gravels observed in the screened intervals (Heath, 1983). The values for BH2206 and BH2212 are inferred to be underestimated for the predominantly sand and gravel lithologies in the screened intervals, due to the aquifer hydraulic characteristic estimation technique used. Slug tests are known to become less reliable when testing gravelly material due to higher transmissivities and the small portion of the aquifer tested by the slug test (Pucko and Verbovšek, 2015); however, slug tests provide a snapshot in time of the current values at that location within the aquifer.

Based on a review of site-investigation bore logs, the saturated thickness of the alluvium is interpreted to be 5–10 m. The site investigation data discussed above results in transmissivity values for the alluvium estimated to range from 1–8 m^2/day.

14.4.1.2 Jurassic to Cretaceous Sediments (Surat Basin)

Occurrence

Jurassic to Cretaceous strata of the Surat Basin underlies the entire proposal site. The alignment is in the Eastern Recharge Groundwater Source of the GAB (DWE, 2008). A review of registered bores surrounding the alignment indicates most bores in the southern portion (Ch 0 km to Ch 22 km) are constructed within the Surat Basin strata.

The depth to the top of the unweathered Surat Basin strata is relatively shallow in the southern portion of the alignment, typically ranging from 10–40 mbgl.

Further north, towards Whalan Creek and the Macintyre River, the overlying alluvium thickens and results in the top of the Surat Basin strata intersected at depths ranging from 50–80 mbgl in registered bores (i.e. GW036693, GW027892, and GW27893).

The key hydrogeological units identified from registered bores installed in Surat Basin strata within a 5 km distance of the alignment include:

- Kumbarilla Beds–observed between Ch 0 km to Ch 20 km below 5–9 mbgl as residual soils and extremely weathered clays in site-investigation boreholes in 2018. Between Ch 20 km and Ch 30 km investigation bores did not encounter the Kumbarilla Beds due to greater thickness of alluvium in this area.
- Walloon Coal Measures—not encountered in investigation boreholes in 2018 and only six registered bores are interpreted to intersect the Walloon Coal Measures, due to the greater depths to this unit, within 5 km of the proposal alignment. The top of this unit is typically encountered at greater than 200 mbgl (i.e. GW009991, GW901938 and RN18136).

The Wallumbilla Formation is recognised as regional aquitard; no registered bores are understood to be screened within this unit and, therefore, it was not considered further in this assessment.

Groundwater recharge, discharge and flow

Registered bores, constructed in the Surat Basin strata, report static groundwater levels (SWLs) to be measured higher than the horizon where water was first intersected (the water strike during drilling). This indicates groundwater resources are under semi-confined to confined conditions that result in the aquifers being less vulnerable to vertical migration of surface contaminants.

Key characteristics of groundwater recharge and discharge in the Jurassic to Cretaceous Surat Basin strata include:

- On a regional scale, groundwater in the Surat Basin system underlies the alluvial aquifers and is mostly sourced from the Pilliga Sandstone in proximity to the groundwater study area. The groundwater is generally fresh and suitable for town water, stock and domestic use, but a high sodium adsorption ratio typically renders these GAB sandstone groundwater resources unsuitable for irrigation (refer Section 14.4.5.2).
- The Surat Basin strata near North Star are influenced by recharge from the GAB intake beds on the western slopes of the Great Dividing Range (NSW DWE, 2009b). These intake beds are associated with younger, fresher water quality, which can support irrigation.
- Discharge is likely to occur via upward leakage (vertical migration) into the overlying alluvium (CSIRO, 2007). Vertical gradients and aquifer interactions are discussed further in Section 14.4.4.

A general northward hydraulic gradient is evident in the potentiometric surface for the Kumbarilla Beds, based on registered bore water levels. Groundwater elevations are observed to decrease with distance and range, from 230–255 mAHD in the southern portion of the proposal near North Star, to 210–220 mAHD near the Boggabilla Road–Bruxner Highway junction, then to 200–210 mAHD near Kurumbul, north of the Queensland border.

Hydraulic properties

There is limited data on aquifer properties from registered bores within the groundwater study area.

Yields from registered bores constructed in the Kumbarilla Beds were found to be low compared to the alluvial aquifers, and range from 0.19 to 1.9 L/s. No pump test data was available for bores within a 5 km radius of the proposal in the Kumbarilla Beds; however, literature values indicate typical horizontal hydraulic conductivity values range from 0.1–0.5 m/day (University of Southern Queensland (USQ), 2011).

Generally, yields from bores constructed within the Walloon Coal Measures are variable and range from 0.2–3.0 L/s (Department of Natural Resources and Mines (DNRM), 2016). Transmissivity values for the Walloon Coal Measures in bores near the NSW/QLD border range from 51 m^2/day (RN15624) to 110 m^2/day (RN15592). Based on DNRME bore cards to infer a saturated thickness of the aquifer, these transmissivities equate to approximate hydraulic conductivities of 3 m/day (RN15624—19 m saturated zone) and 2 m/day (RN15592—63 m saturated zone).

The enhanced groundwater potential is considered to be related to higher permeable coal seams (cleats and fracturing) within the overall Walloon Coal Measures.

14.4.2 Registered groundwater bores

A search of registered groundwater bores within a 10 km radius of the proposal site was completed in August 2018 and revisited in May 2019 to capture any bores registered after August 2018. The DNRME Groundwater Database was used to identify bores located in Queensland. For the NSW portion of the alignment, registered bores were identified using the WaterNSW online database and the *GDE Atlas* (BoM, 2018a). The search identified a total of 197 registered bores within a 10 km radius of the alignment centre line.

Of the 197 registered bores, 86 were excluded from further evaluation due to reported disuse (decommissioned/ abandoned), limited or no data on aquifer lithology, construction details, and/or water quality, all of which are imperative to qualify the existing environment and consideration of potential impacts (e.g. without indication of what aquifer the bore intersects, the level of impact cannot be identified).

The remaining 111 registered bores are detailed in Appendix N: Groundwater Technical Report and depicted on Figure 14.2a–d.

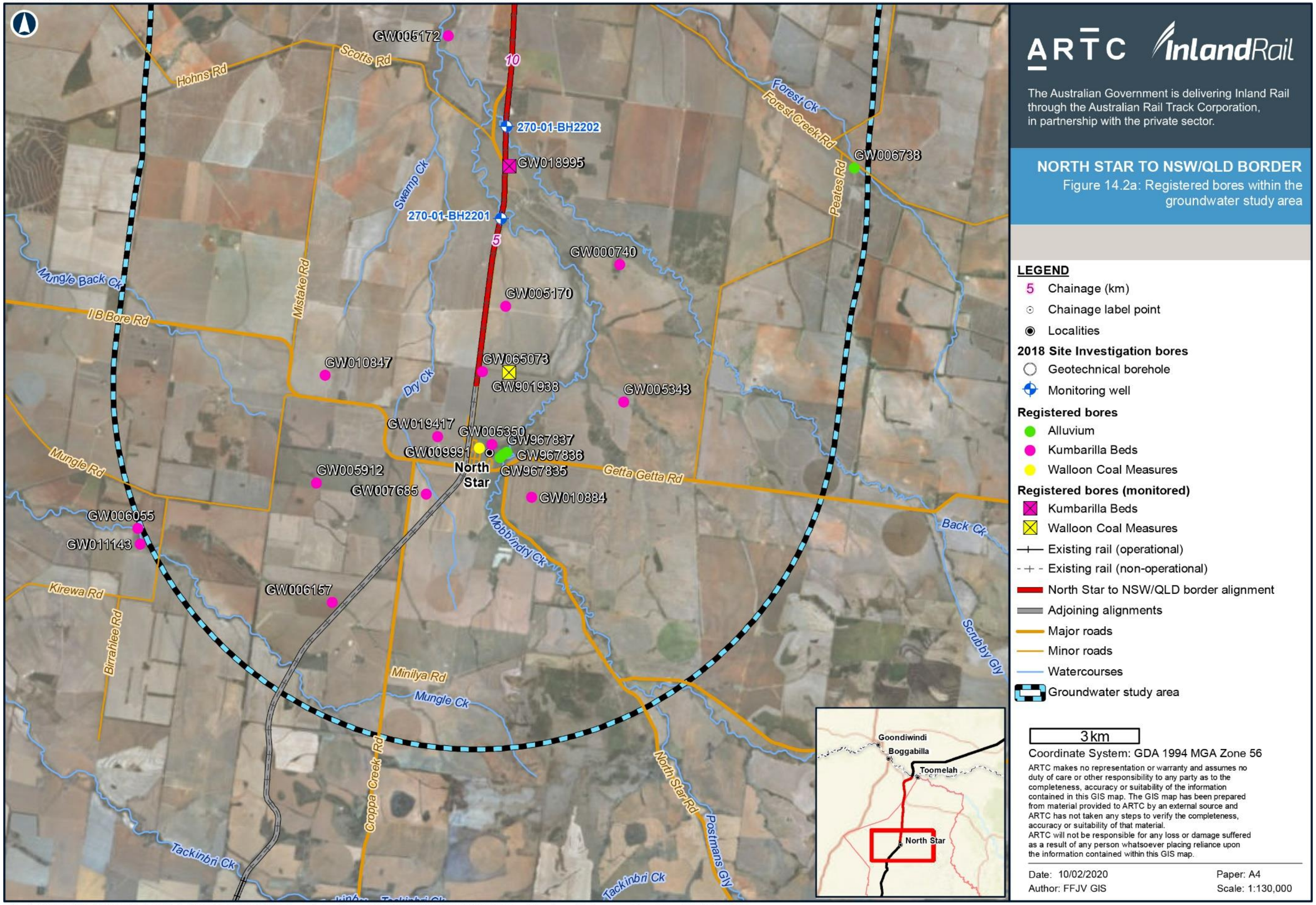
14.4.3 Groundwater levels

14.4.3.1 Cenozoic alluvium groundwater levels

A total of 59 of 111 registered groundwater bores within a 10 km radius of the alignment are constructed within the Cenozoic alluvial sediment aquifers. In many of these bores, the screened interval is shallower than 30 mbgl. Publicly available groundwater level data for these bores includes:

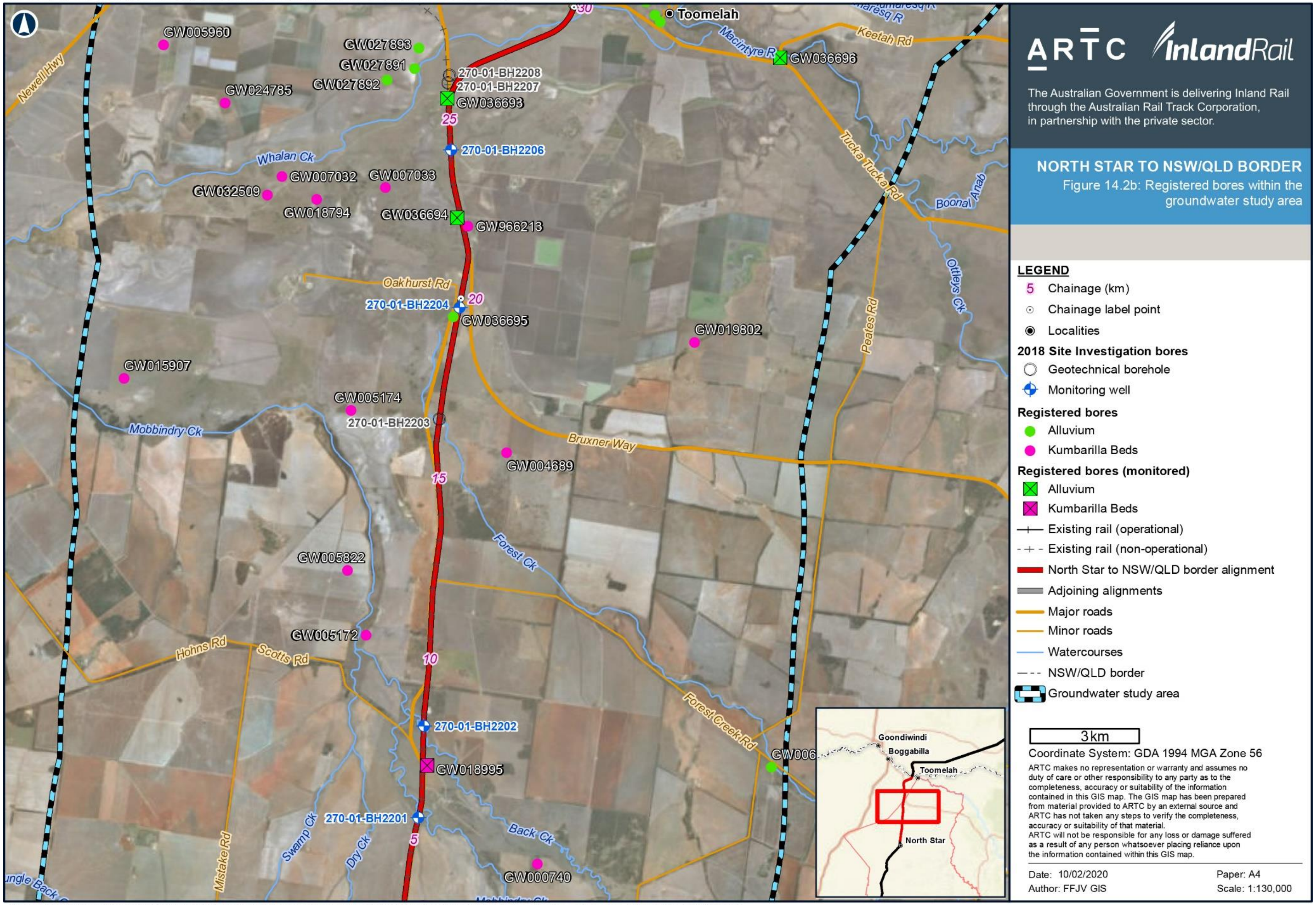
- 37 registered bores reported water levels, which range from 6.1–24.4 mbgl
- 18 registered bores recorded no water levels recorded, 2 of which were dry (GW036695 and GW039278)
- Monthly groundwater level data is available for the period 1987 to 2015 in bores GW036684, GW036694, GW036693 and GW036696. Hydrographs from these bores are in Appendix N: Groundwater Technical Report.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



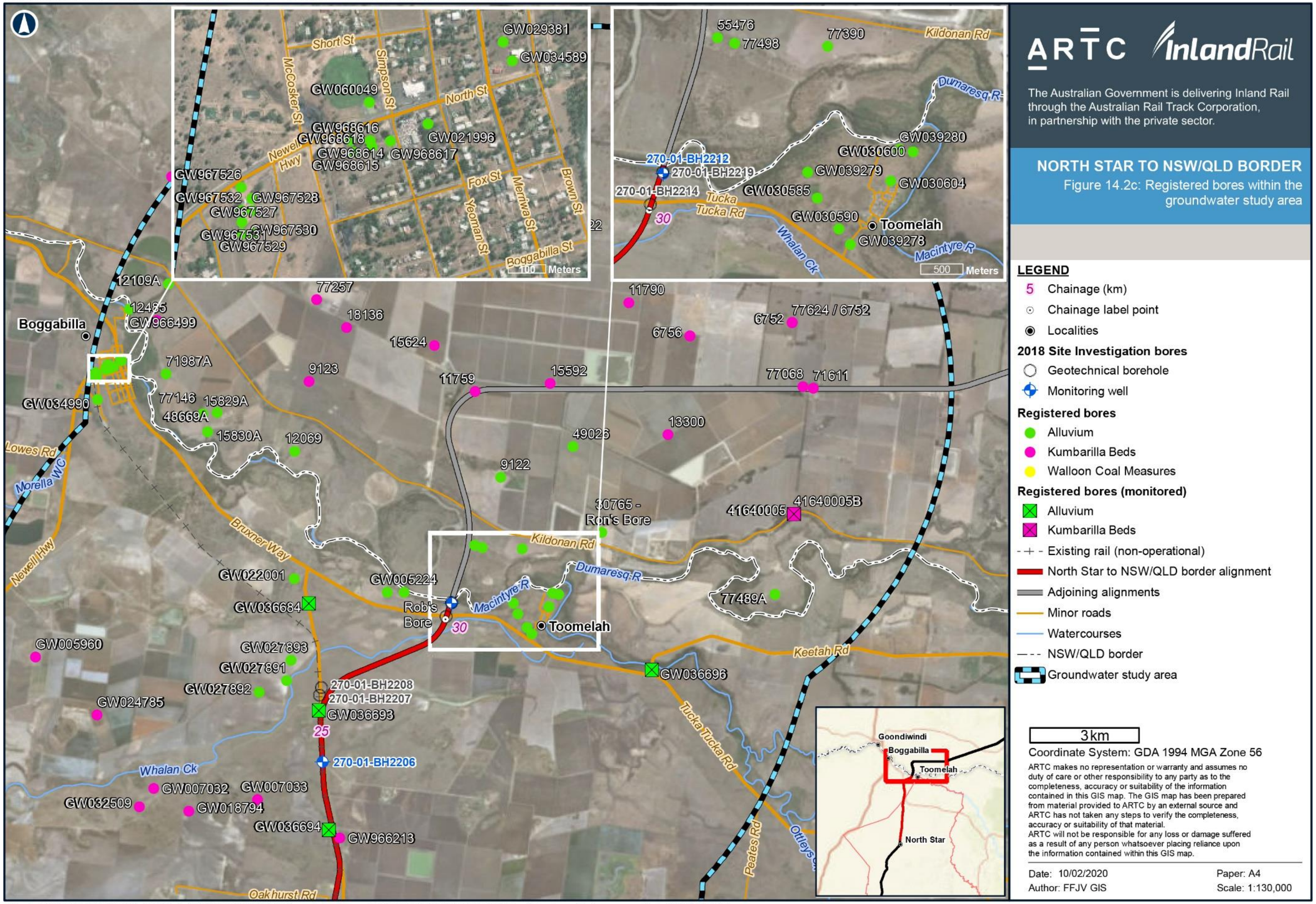
Map by: NWC/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_ARTC_Fig14.2_registeredbores_Rev4_pages_abd.mxd Date: 10/02/2020 12:08

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



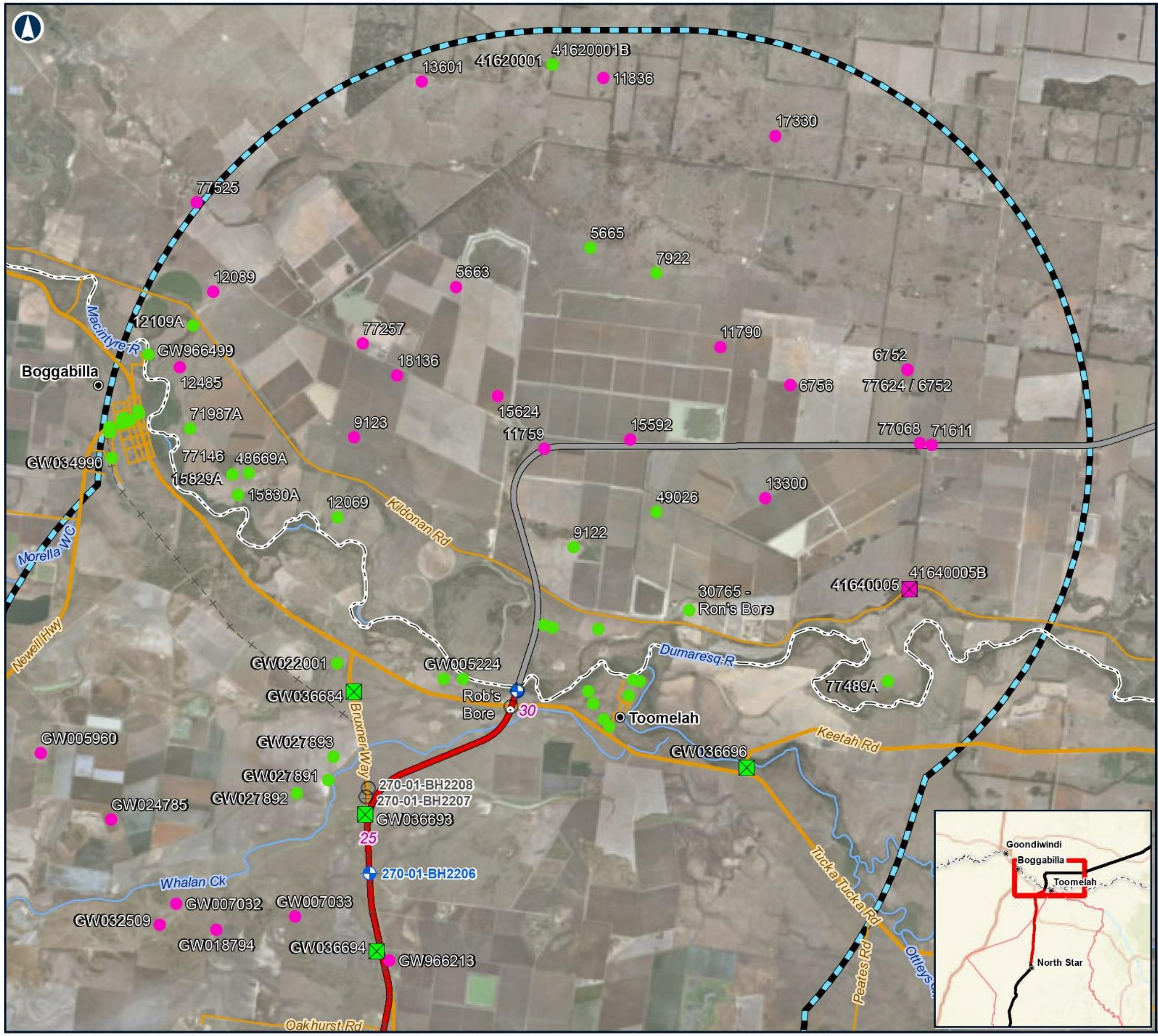
Map by: NWC/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_ARTC_Fig14.2_registeredbores_Rev4_pages_abd.mxd Date: 10/02/2020 11:41

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: NWC/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_ARTC_Fig14.2_registeredbores_Rev4_page_c.mxd Date: 10/02/2020 16:50

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



ARTC InlandRail

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation, in partnership with the private sector.

NORTH STAR TO NSW/QLD BORDER

Figure 14.2d: Registered bores within the groundwater study area

LEGEND

- 5 Chainage (km)
- Chainage label point
- Localities

2018 Site Investigation bores

- Geotechnical borehole
- Monitoring well

Registered bores

- Alluvium
- Kumbarilla Beds
- Walloon Coal Measures

Registered bores (monitored)

- Alluvium
- Kumbarilla Beds
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- Watercourses
- NSW/QLD border
- Groundwater study area

3km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 10/02/2020 Paper: A4
Author: FFJV GIS Scale: 1:130,000

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Long-term natural variations in groundwater levels reported for the alluvial aquifers can range up to 2–2.5 m as evident in the hydrograph for GW036694 (monitored period 1987 to 2015) (refer Appendix N: Groundwater Technical Report). Site- specific groundwater level data from proposal monitoring bores for the period late July to early October 2018 showed similar variations in groundwater levels which ranged from 0.17 m (BH2213) to 1.60 m (BH2212).

A review of monthly rainfall records shows groundwater levels typically increase by 0.5–1 m in response to major rainfall events (i.e. late 2010). Groundwater levels were compared to trends in the cumulative rainfall departure (CRD) from long-term monthly rainfall at Goondiwindi Airport.

There is a general correlation of the cumulative rainfall departure trend to groundwater levels in the alluvium which indicates unconfined conditions with good hydraulic connection to ground surface conditions (e.g. rainfall). An exception is GW036693, located at approximately Ch 25 km, where a weak correlation with the cumulative rainfall departure suggests potentially semi-confined conditions.

14.4.3.2 Jurassic–Cretaceous groundwater levels

Kumbarilla Beds

A total of 49 out of 111 registered bores within a 10 km radius of the alignment are reported to be screened within the Kumbarilla Beds. Based on available data the following can be inferred for groundwater levels within this unit:

- 15 bores had groundwater level data available and indicated the typical groundwater level range of 3.7–36 mbgl
- Static groundwater levels are above the top of the initial water strike, which is consistent with the confined nature of this aquifer
- Sandstone is the dominant lithology reported within the screened intervals.

A representative groundwater level hydrograph for the Kumbarilla Beds is presented in Appendix N: Groundwater Technical Report and is a nested registered bore, 41640005 (pipe A), located 8 km east of the alignment. A long-term (decadal) decline in groundwater levels within the reported shale of the Kumbarilla Beds appears to correlate with the cumulative rainfall departure from long-term monthly rainfall at Goondiwindi Airport. This weak response to the cumulative rainfall departure trend indicates the Kumbarilla Beds are functioning as an aquitard compared to the nested bore constructed in the alluvium, pipe B of registered bore 41640005 (refer Appendix N: Groundwater Technical Report). The registered function of the bore 41640005 is monitoring, not irrigation or water supply, which suggests the trends are representative of natural conditions.

Walloon Coal Measures

Three bores out of the 111 registered bores within the groundwater study area reportedly intersect the Walloon Coal Measures (15624, GW009991 and GW901938). These bores are constructed in sandstone with the screened interval typically at depths greater than 320 mbgl. Registered bore 15624 is reported to be artesian (free-flowing at surface); registered bores GW009991 and GW901938 report average/measured groundwater levels of 7.0 and 25.7 mbgl, respectively.

14.4.4 Vertical gradients and aquifer interaction

Groundwater measurements from nested bores within the alluvium and underlying Kumbarilla Beds were assessed to interpret vertical groundwater gradients. Representative nested bore details and groundwater level data are presented in Table 14.7. Due to a lack of nested bore locations close to the alignment, bores outside the groundwater study area were reviewed to characterise vertical gradients, up to 25 km from the proposal.

TABLE 14.7 VERTICAL GROUNDWATER EVALUATION FORM NESTED BORE DATA FROM THE BORDER RIVERS REGION

Bore	Monitoring point	Depth (mbgl)	Unit	Water level (mAHD)	Distance from study area	Comment
41640005	Pipe B	13–16	Alluvium	220.29	9 km east of the proposal at NSW/QLD border	Downward gradient. Small water level separation between units (levels gauged on 8/05/2017)
	Pipe A	63–69	Kumbarilla Beds	219.10		
GW036691	Pipe 1	13–19	Alluvium	221.41	13 km east of Ch 20 km	Upward gradient. Kumbarilla water level markedly above alluvium water level (levels gauged on 13/10/2015)
	Pipe 2	179–203	Kumbarilla Beds	232.61		
GW036684	Pipe 1	18–26	Upper Alluvium	214	2 km north of Ch 25 km	Negligible vertical gradient. Upper and lower alluvium hydraulically connected (levels gauged on 13/10/2015)
	Pipe 2	29–35	Lower Alluvium	214		
GW036697	Pipe 1	4–8	Upper Alluvium	232.21	25 km east of proposal at NSW/QLD border	Upward gradient. Kumbarilla water level markedly above alluvium water levels (levels gauged on 19/5/2015)
	Pipe 2	52–58	Lower Alluvium	234.30		
	Pipe 3	74–80	Kumbarilla Beds	236.15		

The nested bore data indicates:

- There are notable differences in groundwater levels between the Cenozoic alluvial aquifer (water table) and the Surat Basin strata (potentiometric levels)
- Near Ch 25 km (GW036684), there is little-to-no vertical gradient between the upper and lower alluvial aquifers (i.e. acts as a single unit)
- An upward vertical gradient between the Kumbarilla Beds and the overlying alluvium is evident east of the alignment (GW036697 and GW036691). This observed gradient is also likely to exist along the proposal alignment. The observed upward gradient is likely due to recharge via outcropping units such as the Pilliga Sandstone near the eastern boundary of the GAB, followed by subsequent groundwater movement down hydraulic gradient towards the west.

Hydraulic interaction between alluvial aquifers and the underlying Surat Basin aquifers is likely to be limited due to:

- Low permeability of upper units in the Surat Basin stratigraphy (i.e. Wallumbilla Formation)
- Saprolite development in the upper Surat Basin stratigraphy.

Exceptions may occur where paleochannels are deeply incised, such as in the Macintyre River area, where upward leakage from the Kumbarilla Beds could take place. Another potential mechanism for aquifer interaction is via faults that act as conduits for upward migration of groundwater to shallower systems. Evidence for fault-induced aquifer interactions is documented along the Peel Fault to the east of the proposal where upward leakage of saline groundwater has occurred (Knight et al., 1989). See Appendix N: Groundwater Technical Report for discussion of the Peel Fault.

14.4.5 Groundwater quality

14.4.5.1 Regional salinity

Salinity presents a major land degradation issue that can impact on land salinisation, in-stream salt loads and concentrations. In NSW, Catchment Management Authorities produced salinity risk rankings within each catchment (Catchment Management Authorities are now part of the Local Land Services). This ranking has been developed considering several variables, including salt stores, salinity outbreaks, surface water quality, aquifer type and groundwater quality (NSW DPI, 2013).

Between North Star and Ch 20 km, a very high-risk ranking exists along the proposal site and is associated with the flat-lying Jurassic-aged strata and residual soils of the Kumbarilla Beds and the Walloon Coal Measures (NSW DPI, 2013). These high-risk areas are particularly evident where stratigraphic changes or breaks in slope occur.

Spikes in salinity are known to occur in drainage systems, especially during wet climatic cycles when the local system becomes saturated (NSW DPI, 2013). During such conditions, unconfined, shallow aquifers, such as the alluvium within Mobbindry and Back creeks, could experience spikes in salinity from surface water recharge. Increases in recharge from irrigation also have the potential to increase salinity risks in these high-risk areas.

14.4.5.2 Hydrochemistry

Regional groundwater chemistry is presented in Appendix N: Groundwater Technical Report. Due to a lack of hydrochemistry data from the NSW portion of the alignment, the data presented is from bores located in Queensland within a 10 km radius of the alignment (refer Figure 14.3). This data is considered representative of the alluvial aquifer, the Kumbarilla Beds and the Walloon Coal Measures. Additional site-specific groundwater quality data was collected from seven proposal monitoring bores and three existing landowner bores in October 2018, with this data presented in Table 14.8.

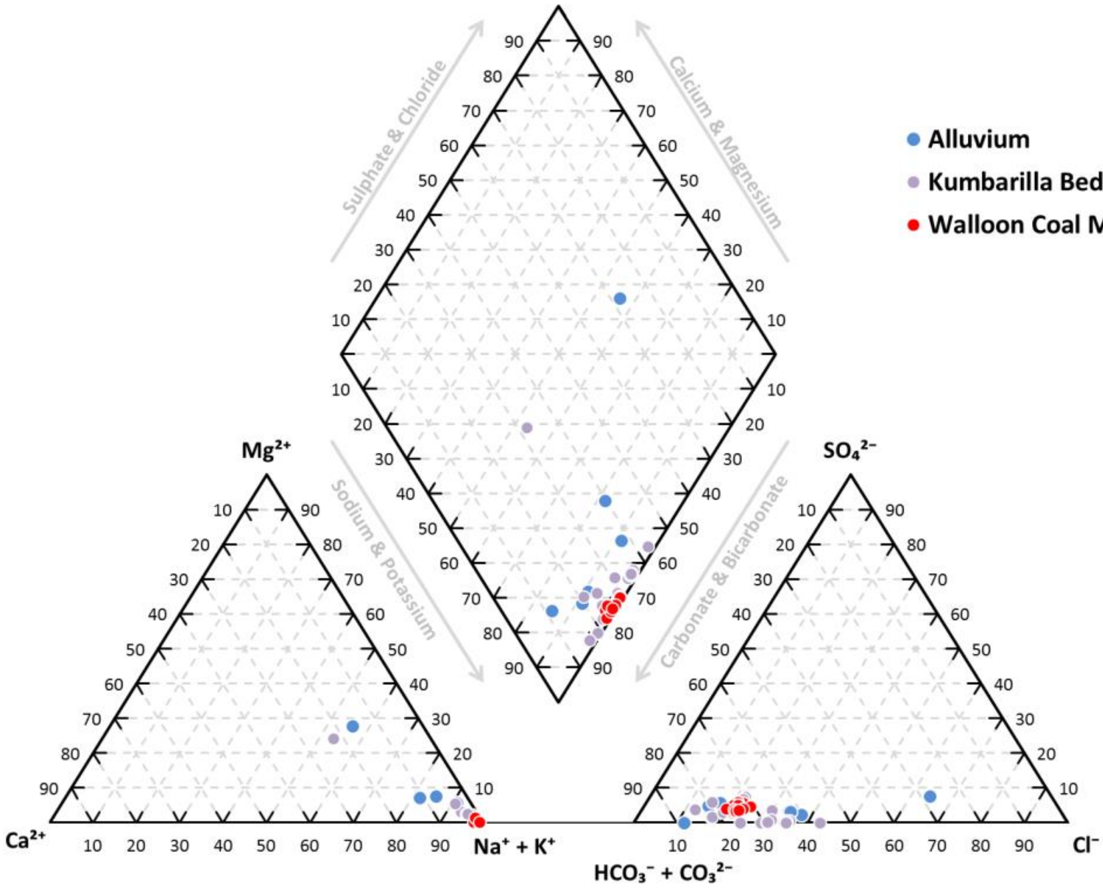


FIGURE 14.3 PIPER PLOT FOR REGISTERED BORES FROM THE KEY AQUIFERS WITHIN 10 KM OF THE NORTHERN PORTION OF THE STUDY AREA

Figure note: Only ionically balanced sample results are displayed.
Source: Queensland Department of Natural Resources, Mines and Energy

TABLE 14.8 SITE INVESTIGATION GROUNDWATER RESULTS OBTAINED IN OCTOBER 2018

Parameter		Kumbarilla Beds	Kumbarilla Beds (inferred)	Wallumbilla Formation	Alluvium						
Bore/Well ID		BH2202	GW965240	BH2204	BH2206	BH2212	BH2213	BH2217	BH2218	Bore X	RN30765
Approx. NS2B location		KP8.1	0.5 km East of KP12.1	KP19.6	KP24.1	KP30.4	KP30.7	KP33.0	KP34.8	1.2 km west of KP30.0	3.4 km east of KP32.0
NS2B Bridge		270-BR02	NA	270-BR04	270-BR06	270-BR10	270-BR10	270-BR12	270-BR13	NA	NA
Field readings	*pH*	6.66	3.24	5.56	7.51	7.07	7.38	7.42	7.35	6.86	7.78
	EC (µS/cm)	12900	43436	23100	2488	813	2096	879	1720	1494	1055
	DO (ppm)	3.77	50.6	4.96	3.29	2.93	1.92	3.45	3.98	9.3	3.49
	Redox (mV)	184.7	338.4	199.8	128.3	10.6	-73.2	92.5	42.3	-1.2	-167.8
Laboratory results	*EC (µS/cm)*	13,600	44,900	23,800	2520	853	1200	926	1760	1450	1110
	TDS (mg/L)	8520	33,100	17,300	1460	507	571	564	1070	993	653
	Na (mg/L)	2380	7800	3390	471	142	250	170	350	123	246
	K (mg/L)	8	8	46	2	3	5	3	7	2	2
	Ca (mg/L)	312	1180	887	29	13	25	18	17	69	5
	Mg (mg/L)	260	1,310	653	26	10	14	9	24	49	3
	Cl (mg/L)	4680	17300	8900	553	154	94	122	246	362	128
	S04 (mg/L)	311	1,460	780	37	44	11	62	37	17	2
	Bicarbonate (mg/L)	959	<1	46	545	160	504	232	588	138	398
	Tot Alk (mg/L)	959	<1	46	545	160	504	232	588	138	398
	Nitrogen (mg/L)	0.31	0.04	0.09	1.22	0.02	0.47	1.4	1.37	184	0.01
	Hardness as CaC03	1850	8340	4900	179	74	120	82	141	374	25

Cenozoic alluvium

Electrical conductivity (EC) data for registered bores in the alluvium indicates salinity is highly variable and ranges up to 4,800 microsiemens per centimetre (µs/cm), which represents fresh to brackish groundwater quality. Laboratory reported values for total dissolved solids (TDS), primarily from the Macintyre River alluvium, indicate the alluvium in the northern portion of the alignment is fresh and potable as TDS is below the *Australian Drinking Water Guidelines* of 600 mg/L for TDS (National Health and Medical Research Council (NHMRC), 2011). Site-specific groundwater sampling in the alluvium bores in October 2018 is broadly consistent with the regional bore data with salinity typically less than 2,000 µS/cm. The highest salinity was recorded in BH2206 near the proposed bridge 270-BR06 with a concentration of 2,488 µS/cm in the alluvium (refer Table 14.8). Based on TDS values from registered bores and site-investigation bores, the alluvium slightly exceeds the drinking water guideline of 600 mg/L.

Regional monitoring from the NSW Border Rivers Unregulated and Alluvial Water Sources considers the Border Rivers—Downstream Keetah Bridge Alluvial Water Source (i.e. Macintyre River and Whalan Creek alluvial units) to have high salinity unsuitable for irrigation, with values typically ranging from 14,000–50,000 µS/cm (DPI, 2015).

Based on available registered bore data and the October 2018 sampling, the field measured pH ranges from 7.0–8.0 in the alluvium, which indicates neutral to slightly alkaline conditions.

Major ion chemistry for the alluvium displays the most variability and is likely a result of the different parent material in the alluvium sequences (refer Figure 14.3).

Based on the October 2018 sampling, no hydrocarbons or pesticides were detected in the alluvial aquifer along the proposal alignment.

Kumbarilla Beds

Groundwater quality from registered bores constructed within the Kumbarilla Beds shows TDS values that range from 333–1,100 mg/L, while two locations sampled close to the alignment in October 2018 indicate TDS values can exceed 8,000 mg/L (Appendix N: Groundwater Technical Report and Table 14.8). The site-investigation bores were installed in the shallower weathered zone of the Kumbarilla Beds, which may have contributed to higher salinity compared to the deeper registered bores in this aquifer, due to the weathered nature of sediments, which can restrict groundwater flow and result in higher concentrations due to accumulation. Groundwater quality from registered and site-investigation bores were typically above the *Australian Drinking Water Guidelines* value of 600 mg/L for this aquifer (NHMRC, 2011).

Major ion chemistry is highly variable and likely to reflect the variety of formations monitored within the Kumbarilla Beds.

Walloon Coal Measures

Available salinity data indicates the Walloon Coal Measures typically have brackish to slightly brackish groundwater quality but are still suitable for stock usage (TDS <4,000 mg/L). Major ion chemistry displays are well defined when compared to the other formations, with higher proportions of sodium and potassium. No site-investigation bores were constructed to monitor the Walloon Coal Measures as this unit is not anticipated to be intersected by the proposal.

14.4.6 Surface water–groundwater interactions

Regional assessments of surface water–groundwater interactions have identified the Macintyre River and other water courses in the region to generally be of a losing condition (Parsons et al., 2008). This means surface water infiltrates vertically to underlying aquifers and acts to recharge local groundwater within the alluvial sediments; however, a reversal to gaining conditions can occur over short time periods, e.g. in response to flood events that saturate the local alluvial aquifers, which, in turn, vertically migrate upwards and laterally outward as base flow, and can recharge surface water features.

The relationship between flow rates in the Macintyre River and groundwater elevation in the associated alluvial system are discussed in Appendix N: Groundwater Technical Report. To summarise, high-flow periods, such as in late 2010, correlate with responses ranging from 1 m (GW036684 and GW036696) to 2 m (GW036694) water level increases. The strongest hydraulic connection to river flow can be observed in GW036696, which is located in alluvial sediments in close proximity to the active river channel.

The Glenlyon and Pindari dams in the upper reaches of the Border Rivers Catchment result in regulated flows to the Severn and Macintyre rivers (DPI, 2012b). Consequently, there is likely to be an artificial influence on recharge to alluvial aquifers during low flow periods (periods of dam discharge to the rivers).

14.4.7 Groundwater dependent ecosystems

An assessment of potential groundwater dependent ecosystems (GDEs) was undertaken via review of the following data sources:

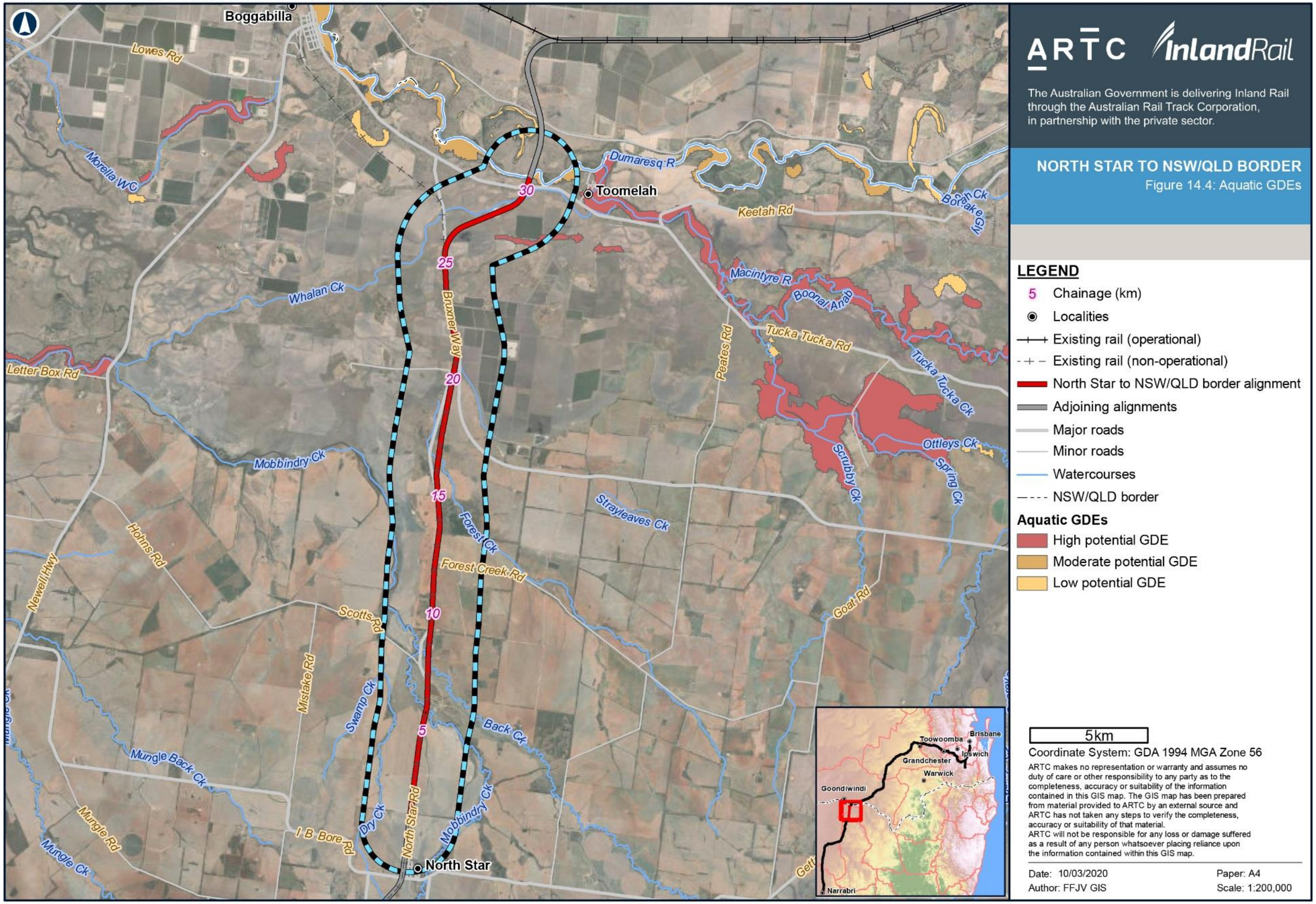
- Relevant NSW Water Sharing Plans, which include scheduled listings of high-priority GDEs
- Bureau of Meteorology *Groundwater Dependent Ecosystems Atlas* (BoM, 2018a)
- Findings within Chapter 11: Biodiversity.

The *Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources* (DPI, 2012b) does not list any high-priority GDEs within Schedule 8 of the plan.

No scheduled high-priority GDEs are included in the *Water Sharing Plan for the NSW Border Rivers Regulated River Water Source* (DWE, 2009b).

The GDE Atlas (BoM, 2018a) was interrogated to identify and assess for potential GDEs within or near the proposal site. An approximate 2 km radius around the alignment centreline was reviewed for potential GDEs, as a conservative approach, to assess potential proposal impacts on sensitive receptors. An overview of potential aquatic and terrestrial GDEs is on Figure 14.4 and Figure 14.5, respectively. Detailed figures of the potential GDE locations are in Appendix N: Groundwater Technical Report. Not all water features are shown in the figures due to the scale of the figure compared to the size of the feature.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

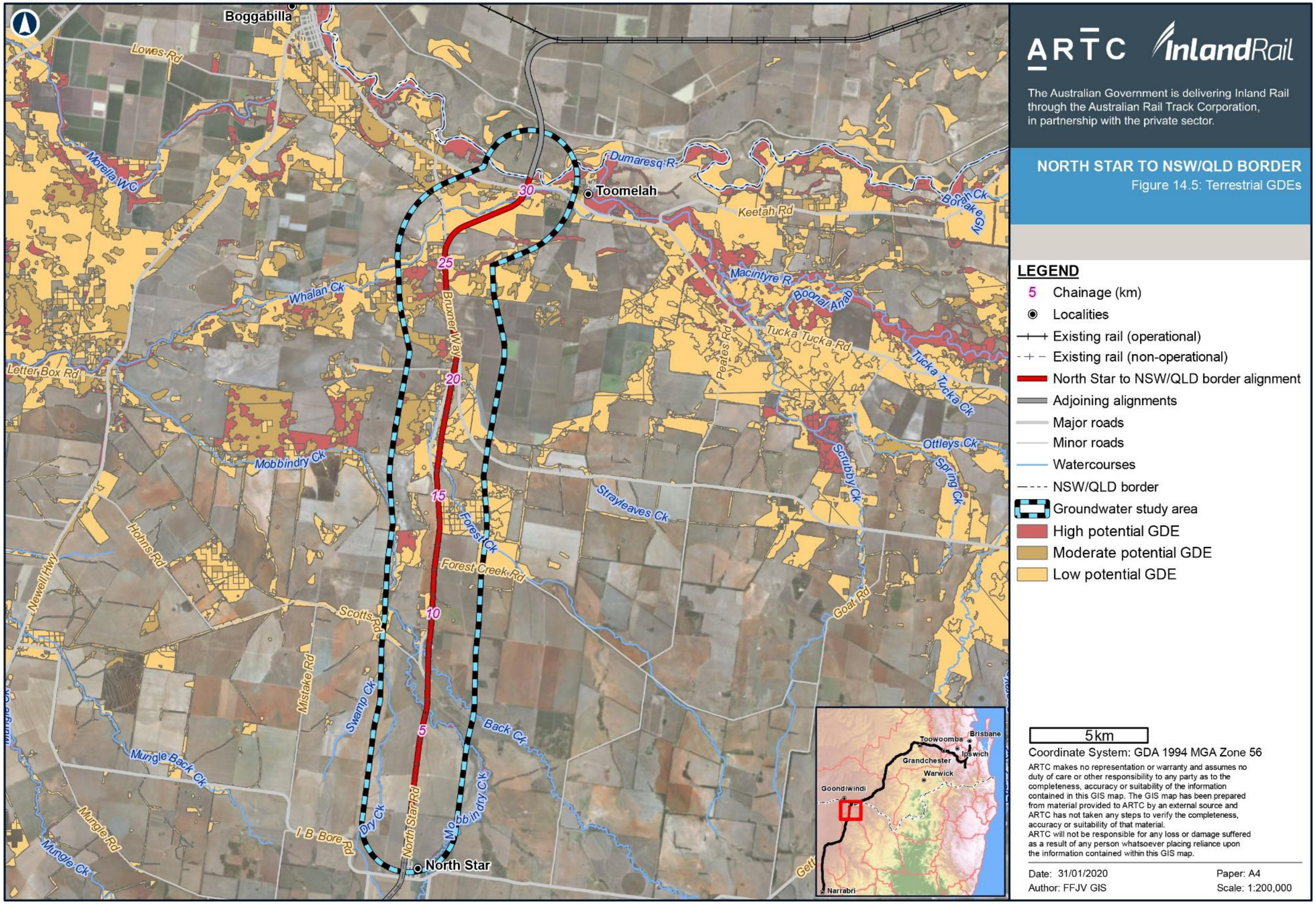


Map by: NCW Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_Figure_14.4_Aquatic GDE Figure_Rev4.mxd Date: 10/03/2020 15:12

FIGURE 14.4 AQUATIC GROUNDWATER DEPENDENT ECOSYSTEMS

Source: BoM (2018a)

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: NCW Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_Figure_14.5_Terrestrial GDE Figure_Rev3.mxd Date: 31/01/2020 16:02

FIGURE 14.5 TERRESTRIAL GROUNDWATER DEPENDENT ECOSYSTEMS

Source: BoM (2018a)

14.4.7.1 Aquatic groundwater dependent ecosystems

Mapped potential aquatic GDEs are limited within the 2 km radius of the groundwater study area; no high-potential aquatic GDEs are proposed to be intersected by the proposal. A summary of aquatic GDEs is provided in Table 14.9.

TABLE 14.9 SUMMARY OF AQUATIC GROUNDWATER DEPENDENT ECOSYSTEMS

Chainage	GDE category	Aquatic GDE description
Ch 5.70 km	Moderate	A narrow corridor reported to have moderate potential as an aquatic GDE is identified in Mobbindry Creek. Proposed construction at this location is a bridge over Mobbindry Creek. Classified ecosystem type is river.[1]
Ch 28.0 km	High	A high-potential aquatic GDE is identified at Malgarai Lagoon located 1 km to the south-east of the alignment and 2.5 km south of the Macintyre River. Classified ecosystem type is wetland. No construction activity in proximity to this feature.
Ch 30.5 km	Moderate	A moderate-potential aquatic GDE is identified within the active Macintyre River channel and will be crossed by the alignment via a cut-and-fill as well as a bridge structure. Classified ecosystem type is wetland.

Table note:
1. The GDE database (developed by BoM (2018a)) classifies this waterway as a river.
Source: *GDE Atlas* (BoM, 2018a)

Based on site inspections and the desktop review in Chapter 11: Biodiversity, the Macintyre River is considered the primary waterway in the proposal area, with habitat that could support six threatened aquatic species identified as having a 'possible' likelihood of occurring within the proposal area. This includes the following species: Darling River snail (*Notopala sublineata*), silver perch (*Bidyanus bidyanus*), southern purple spotted gudgeon (*Mogurnda adspersa*), Murray cod *(Maccullochella peelii),* eel-tailed catfish (*Tandanus tandanus),* and western olive perchlet (*Ambassis agassizii*). As discussed in Section 14.4.6, the Macintyre River is hydraulically connected to the alluvial aquifers and, as such, indirectly supports these species.

14.4.7.2 Terrestrial groundwater dependent ecosystems

Moderate- to high-potential terrestrial GDEs are mapped within the 2 km radius groundwater study area for GDEs; these GDEs are summarised in Table 14.10 and shown in Figure 14.5.

TABLE 14.10 SUMMARY OF TERRESTRIAL GROUNDWATER DEPENDENT ECOSYSTEMS

Chainage	GDE Category	Terrestrial GDE description
Ch 5.70 km	High	High-potential terrestrial GDEs within the floodplains of Mobbindry Creek. This GDE is characterised by red river gums and open tall forest associated with flood plains. The alignment intersects this feature with a short section of bridge proposed.
Ch 8.1 km	High	High-potential terrestrial GDEs within the active channel of Back Creek. This GDE is characterised by red river gums and open tall forest associated with the flood plains. The alignment intersects this feature with a short section of cut-and-fill proposed.
Ch 23.6 km to Ch 25.0 km	Moderate to high	Moderate- to high-potential, irregularly distributed terrestrial GDEs on the alluvial plains, south of and along Whalan Creek. Characterised by River Coobah swamp wetland.
Ch 29.4 km to Ch 29.8 km	High	High-potential terrestrial GDE within the active channel of Whalan Creek. Cut-and-fill proposed in this area. Characterised by River Coobah swamp wetland.
Ch 30.4 km to Ch 30.7 km	High	High-potential terrestrial GDEs on the Macintyre River with red river gums, open tall forest, and marsh grassland associated with these flood plains.

Source: *GDE Atlas* (BoM, 2018a)

14.4.7.3 Subterranean

No known or potential subterranean GDEs have been mapped within the *GDE Atlas* (BoM, 2018a) within the GDE groundwater study area.

14.4.8 Groundwater use

A review of licensed groundwater allocations for the primary aquifers covered by water sharing plans in the region was completed by searching the WaterNSW licence register (refer Table 14.11).

Water access licence (WAL) allocations for the main alluvial aquifer (NSW Border Rivers—Downstream Keetah Bridge) is limited to two licences, which are allowed to extract groundwater up to a total of 485 ML per year. This limited extraction allocation contrasts with the more productive alluvial unit to the east of the Keetah Bridge ('Upstream Keetah Bridge Water Source') (DPI, 2012b). The Eastern Recharge Groundwater Source (i.e. GAB) forms a significant water source for the region, with 17,487 ML per year allocated under 79 access licences.

TABLE 14.11 SUMMARY OF 2018–2019 WATER ACCESS LICENCE ALLOCATIONS RELEVANT TO THE GROUNDWATER STUDY AREA

Water source	Licence type	No of WALs	Water made available (ML/yr)
NSW Border Rivers—Downstream Keetah Bridge (Alluvial Water Source)	Aquifer	2	485
Croppa Creek and Whalan Creek (Surface Water and Alluvial Water Source)	Domestic and stock	9	65.5
	Domestic and stock (domestic)	1	2
	Domestic and stock (stock)	2	10
	Unregulated river	22	15,674
GAB—Eastern Recharge Groundwater Source	Aquifer	79	17,487
	Domestic and stock (town water)	1	32

Source: WaterNSW

A summary of groundwater use, based on registered bores, is in Figure 14.6. A total of 104 of the 111 registered bores within a 10 km radius of the proposal site provided sufficient data to assess the category of bore use and the corresponding aquifer. Based on the location, depth and lithology of these registered bores, the following can be deduced about water usage:

- In the northern portion of the alignment (Ch 20 km to Ch 30 km) bores are constructed predominantly within the Cenozoic alluvial aquifer with the type of bore/groundwater use ranging widely. Bores located near the Macintyre River are predominantly used for water supply and domestic purposes (i.e. Toomelah township 2 km east of the alignment). Three bores within the alluvium to the east of Ch 25 km are reported to be irrigation bores (GW027891, GW027892 and GW027893).
- Bore use in the southern portion of the alignment (i.e. Ch 0 km to Ch 20 km) is dominated by extraction from the Kumbarilla Beds and the Walloon Coal Measures for stock and, to a lesser extent, irrigation and domestic purposes. This reflects the limited extent of alluvium in the southern portion and the generally higher salinity associated with the deeper hydrostratigraphic units (refer Section 14.4.5.2).

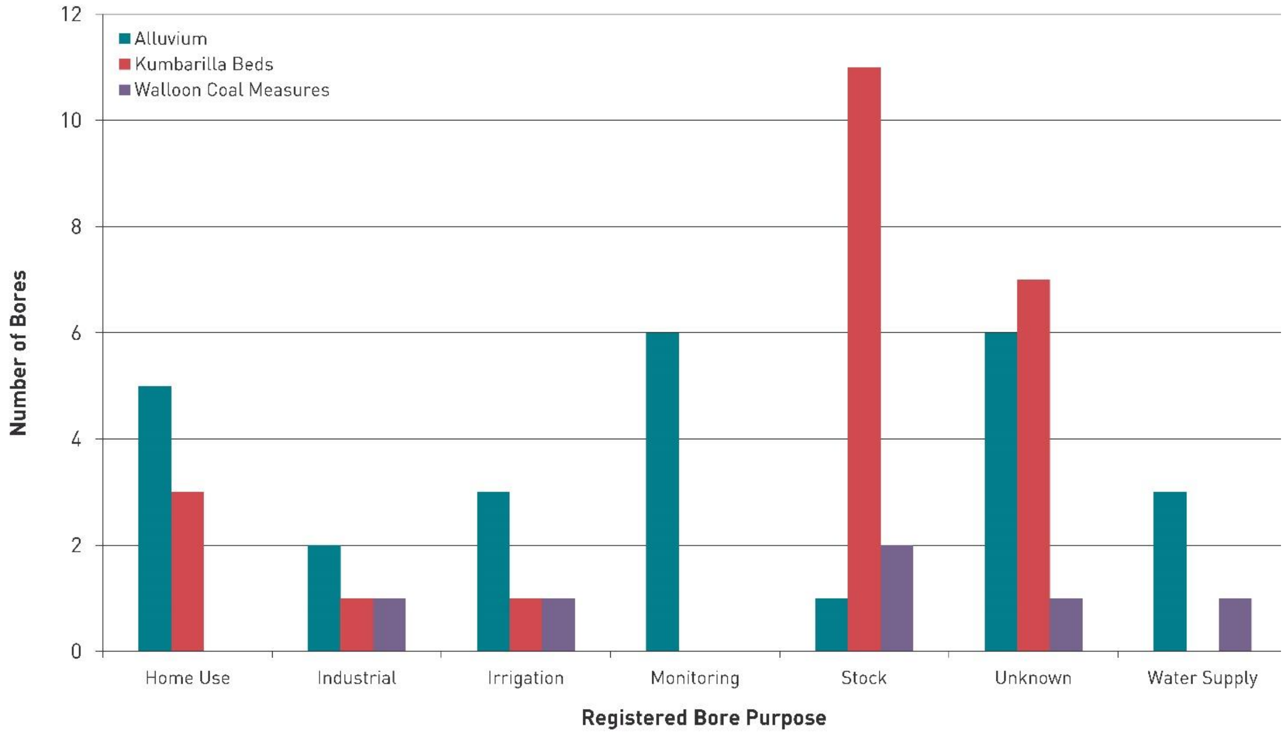


FIGURE 14.6 REGISTERED BORE USE WITHIN A 10 KM RADIUS OF THE PROPOSAL SITE

14.4.9 Groundwater environmental values

This section discusses the groundwater-related environmental values relevant to the proposal site. The NSW Office of Water (formerly part of the Department of Environment and Conservation) has defined environmental values and long-term goals for NSW's water quality in each catchment region. The *Border Rivers (NSW) Water Quality and River Flow Objectives* (Department of Environment, Climate Change and Water (DECCW), 2006) provide relevant groundwater environmental values and trigger values for the proposal, summarised in Table 14.12.

14.4.9.1 Environmental values of the proposal

Aquatic ecosystems

Regional aquatic GDE data evaluated in Section 14.4.7 indicates no high-potential aquatic GDEs are intersected by, or in close proximity to, the proposal site (refer Figure 14.4). The nearest high-potential aquatic GDE is located at Malgarai Lagoon approximately 1 km to the east of the alignment. The Macintyre River is mapped as a moderate-potential GDE located at the end of the proposal; therefore, this environmental value is considered relevant to the proposal.

Visual amenity

Visual amenity is not applicable to groundwater as no springs have been identified in or adjacent to the alignment.

Farm water supply and use

Groundwater quality results presented in Section 14.4.5 indicate that groundwater abstracted from the shallow alluvial aquifer could be used for general farm purposes, although quality is noted to be highly variable. This environmental value is considered relevant to the proposal.

Stock water

In Section 14.4.8, registered bore use and the allocation of water access licences were reviewed. This review confirmed that groundwater from the alluvium, and particularly the Kumbarilla Beds, is predominantly used for stock watering. Available salinity data in Section 14.4.5 indicates that the Cenozoic alluvium and Surat Basin aquifers are generally suitable for stock-watering purposes (i.e. < 4,000 mg/L for beef cattle as per ANZ Guidelines (2018)).

Groundwater results from site investigations in October 2018 further confirmed the suitability of groundwater from the Cenozoic alluvium for stock-watering purposes (refer Table 14.8). This environmental value is considered relevant to the proposal.

Recreation

This environmental value is generally not considered relevant to in-situ groundwater and is a more common consideration for surface water. There is a possibility of seasonal bore water use to fill swimming pools. There are no registered groundwater springs within the groundwater study area that could be considered for recreational use.

This environmental value is not considered relevant to the proposal.

Drinking water

Water from bores constructed within the Kumbarilla Beds and the Walloon Coal Measures are generally unsuitable for drinking water (i.e. greater than the *Australian Drinking Water Guidelines* criteria of 600 mg/L TDS (NHMRC, 2011)).

Results for TDS from the Cenozoic alluvium within the Queensland portion of the alignment indicate the alluvium is suitable for drinking water (based on salinity).

It is unclear if the registered bores designated for water supply near the Toomelah Aboriginal Community are treated to mitigate any salinity issues.

As numerous registered bores within alluvial sediments reported uses and WAL for domestic uses, this environmental value is considered relevant to the proposal in a conservative measure.

Irrigation

Irrigation sourced from groundwater is an important value to the region, particularly in the North Star area with respect to the proposal. Irrigation in this area is primarily used for cotton production and, to a lesser extent, other irrigated crops such as cereals (NSW DWE, 2009b). The threshold salinity tolerances for plants grown in loamy to clayey soils (considered the primary soil conditions in the proposal area) are 600 µS/cm to 7,200 µS/cm as stated in the ANZ Guidelines (2018). Based on salinity results presented in Section 14.4.5, the alluvium and Surat Basin strata generally report concentrations of salinity less than 2,000 µS/cm in the area, indicating groundwater is suitable for irrigation. An exception is bores constructed to intersect the upper weathered zone of the Surat Basin Kumbarilla Beds strata, where site investigation bores have reported an association with salinity over 10,000 µS/cm (i.e. BH2202 and BH2204 in Table 14.8).

This environmental value is considered relevant to the proposal.

Cultural water

A review of the NSW Aboriginal Places and State Heritage Register and the Moree Plains and Gwydir Local Environmental Plans indicate there are no registered water sites of Aboriginal cultural significance in close proximity to the proposal site.

This environmental value is not considered relevant to the proposal.

14.4.9.2 Summary of groundwater environmental values

Based on this review, the groundwater environmental values mapped using available local and regional information and site investigation results that are considered to be relevant to the proposal include:

- Drinking water (Cenozoic alluvium only)
- Domestic use (Cenozoic alluvium and Surat Basin aquifers)
- Stock watering (Cenozoic alluvium and Surat Basin aquifers)
- Irrigation (Cenozoic alluvium and Surat Basin aquifers)
- Aquatic GDEs (Macintyre River).

14.4.9.3 Water quality objectives

The relevant water quality objectives (WQO), based on the identified environmental values for the proposal, and trigger values, are in Table 14.12 for the Border Rivers Catchment.

Based on the data in Table 14.12, the following analytes are currently in exceedance of the identified WQOs and, therefore, these WQOs cannot be maintained or achieved over time:

- Aquatic ecosystems (alluvial aquifers): total phosphorous, total nitrogen, and likely salinity (as electrical conductivity) in some areas
- Livestock water supply (Surat Basin aquifers): TDS
- Irrigation water supply (alluvial and Surat Basin aquifers): chloride, sodium
- Homestead water supply:
  - Alluvial aquifers: likely TDS in some areas
  - Surat Basin aquifers: TDS, pH
- Drinking water—Groundwater (alluvial aquifers): likely TDS in some areas.

TABLE 14.12 ENVIRONMENTAL WATER QUALITY VALUES RELEVANT TO GROUNDWATER FOR THE BORDER RIVERS CATCHMENT

Water quality value	Description	Relevant groundwater unit	Relevant trigger values[1,2]	Comparison to existing environment
Aquatic ecosystems	Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term. The objective applies to all natural waterways, as well as any artificial water courses that flow into natural waterways. Specific trigger values are defined for each waterbody type including upland rivers, lowland rivers and lake or reservoirs.	Macintyre River (direct); alluvial aquifers (indirect)	Total Nitrogen: 0.5 mg/L (lowland rivers) Total phosphorus: 0.025 mg/L (lowland rivers) pH—upland rivers: 6.5–8.5 (lowland rivers) Salinity (EC)—125–2,200 µS/cm (lowland rivers).	Site-investigation bores' analytical results (Table 14.8) for alluvial aquifers (indirect WQO) compared to the WQOs: - Electrical conductance: below the trigger values, except location BH2206 (2,520 µS/cm) - pH: within WQOs - Total P: all results are above the trigger value (0.07 mg/L to 0.47 mg/L) - Total N: all results are above the trigger value except Ron's bore (0.3 mg/L), BH2206 and BH2217 (both 0.4 mg/L).
Livestock water supply	Protecting water quality to maximise the production of healthy livestock and applies to all surface and groundwater	Alluvium aquifers Surat Basin aquifers	TDS—no adverse impacts values as per ANZ Guidelines (2018): - Beef cattle: 0–4,000 mg/L - Sheep: 0–5,000 mg/L - Horses: 0–4,000 mg/L.	Site-investigation bores analytical results (Table 14.8) compared to the WQOs: - Alluvium aquifers: all below 4,000 mg/L - Surat Basin aquifers: all above 5000 mg/L.

Irrigation water supply	Protecting the quality of waters applied to crops and pasture. Applies to all current and potential areas of irrigated crops, both small scale and large scale.	Alluvium aquifers
		Surat Basin aquifers
			Trigger values as per ANZ Guidelines, 2018:
			- Chloride (Cl): tolerant crops >700 mg/L
			- Sodium (Na): tolerant crops >460 mg/L
			- Bicarbonate (HCO_3^-): no trigger value.
				Site-investigation bores analytical results (Table 14.8) compared to the WQOs:
				- Chloride:
				  - Alluvium aquifers suitable for sensitive to moderately tolerant crops (94 mg/L to 553 mg/L)
				  - Surat Basin aquifers all above 700 mg/L (4,680 mg/L to 17,300 mg/L)
				- Sodium:
				  - Alluvium aquifers suitable for sensitive to tolerant crops (123 mg/L to 471 mg/L)
				  - Surat Basin aquifers all above 460 mg/L (2,380 mg/L to 7,800 mg/L).

Water quality value	Description	Relevant groundwater unit	Relevant trigger values[1,2]	Comparison to existing environment

Homestead water supply	Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing. Applies to all homesteads that draw water from surface and groundwater for domestic needs, including drinking water.	Alluvium aquifers
		Surat Basin aquifers
			TDS:
			- <500 mg/L (good quality drinking water).
			- 500 to 1,000 mg/L (acceptable).
			- >1 000 mg/L (unsatisfactory taste and corrosive).
			- pH 6.5 to 8.5.
				Site-investigation bores analytical results (Table 14.8) when compared to the WQOs are:
				- Total dissolved solids:
				  - Alluvium aquifers all above 500 mg/L but below 1000 mg/L except BH2206 (1460 mg/L)
				  - Surat Basin aquifers all above 1,000 mg/L
				- pH:
				  - Alluvium aquifers all within trigger value range
				  - Surat Basin aquifers all outside of trigger value range except BH2202 (6.66)

Drinking water—groundwater	Refers to the quality of drinking water drawn from the raw surface and groundwater sources before any treatment. Applies to all current and future licensed offtake points for town water supply and to specific sections of rivers that contribute to drinking water storages.	Alluvium aquifers	TDS (*Australian Drinking Water Guidelines* 2011 values):
			- 0–600 mg/L (good)
			- 600–900 mg/L (fair)
			- 900–1200 mg/L (poor)
			- >1200 mg/L (unacceptable)
			- pH: 6.5–8.5
				Site-investigation bores analytical results (Table 14.8) when compared to the WQOs are:
				- TDS:
				  - Alluvium aquifers good to poor, except BH2206, which is unacceptable (1,460 mg/L)
				- pH:
				  - Alluvium aquifers all within trigger value range

Table notes:
1. Trigger values sourced from the NSW Water Quality and River Flow Objectives online database (NSW DEC).
2. Aquatic ecosystem trigger values are for lowland rivers given the DEC-suggested altitude for upland rivers in the NSW Murray–Darling Basin of >250 m.

Source: DPI (2006)

14.5 Field investigations

Geotechnical and hydrogeological site investigations were undertaken along the Project from July to October 2018. Results from these investigations have been considered in Section 14.4 to complement the desktop geological and hydrogeological reviews.

The hydrogeological field investigations included:

- Standpipe piezometer installation
- Permeability testing in standpipe piezometers
- Groundwater level monitoring
- Groundwater sampling
- Bore inventory and groundwater sampling of registered bores and private property bores.

Site investigations (geotechnical and hydrogeological) are summarised in Table 14.13.

TABLE 14.13 SUMMARY OF SITE INVESTIGATIONS COMPLETED IN JULY TO OCTOBER 2018

Investigations		Purpose	Methodology and details	Applicability to the Groundwater Technical Report
Geotechnical investigations	Geotechnical boreholes	Inform the geotechnical properties of the soil profile and characterise depth to basement near proposed bridge sections	15 locations drilled using hollow-stem augers followed by rotary drilling (water) Selected locations were converted to groundwater monitoring wells	Stratigraphic information from bore logs at bridge sections, including aquifer lithology and overlying lithotypes (refer Section 14.4.1) Intersection of groundwater table ('water strike')
	Auger boreholes	Inform the geotechnical properties of the soil profile along the alignment	18 auger holes completed using the solid-stem auger method to a target depth of 3 mbgl	Characterise the soil profile overlying aquifers Identify potential shallow groundwater in alluvium
	Test pits	Provide assessment of the pre-existing rail formation	Total of 42 test pits completed with an excavator to a maximum depth of 2.3 mbgl	
	Seismic Refraction (SR) surveys	Complement the intrusive investigations Assess depths to bedrock at bridge sites	13 seismic refraction survey lines were completed	Provide an indication of the thickness of alluvial aquifers near bridge sections
Hydrogeological investigations	Standpipe piezometer installation	Characterise the existing groundwater regime, particularly bridge sections	8 monitoring wells installed with 50 mm class 18 PVC with 0.4 mm slotted screen intervals Well details are provided in Table 14.14	
	Groundwater level monitoring		Groundwater levels measured in all proposal monitoring wells using a manual dip meter and continuous level loggers (In-Situ Rugged TROLL®) from July to October 2018. Level loggers set to record on an hourly basis	Confirm depths to groundwater and fluctuations in groundwater levels Discussed further in Sections 14.4.1 and 14.4.3

Investigations		Purpose	Methodology and details	Applicability to the Groundwater Technical Report
	Permeability testing		6 wells with slug tests completed Hydraulic conductivity was estimated using AQTESOLV Pro 4.0 via the Hvorslev and KSG solution methods	Provides additional data on aquifer properties discussed in Section 14.4.1
	Groundwater sampling		7 monitoring wells sampled manually using a bailer 3 landowner bores were also sampled. Field parameters were collected during sampling	Analytical suites include major ions, pH, conductivity, TDS, metals, nutrients, hydrocarbons and pesticides Results are discussed further in Section 14.4.5

Source: ARTC, 2018

14.5.1 Standpipe piezometer installation

Drilling and installation of standpipe piezometers was conducted according to the *Minimum Construction Requirements for Water Bores in Australia—Edition 3* (National Water Commission, 2012). The design of the standpipe piezometer was provided by a qualified hydrogeologist, with installation conducted by the drilling contractor under the supervision of a qualified field engineer. A Queensland and NSW licensed (Class 2) water bore driller was onsite during the installation of the standpipe piezometer installation.

All standpipe piezometers were equipped with 50 mm diameter, class 18 PVC screw-jointed pipes with 0.4 mm slotted screens and blank casing. A borehole diameter of 96 mm was drilled for the installation of the standpipe piezometers. A filter pack (1–3 mm washed and graded sand/gravel) was placed in the annulus of the borehole around the screen section, which was then sealed with a bentonite plug. The annular space above the bentonite plug was grouted to the surface, where a protective monument or gatic cover was installed.

The completed standpipe piezometers were flushed after installation to remove drilling fluid (drill muds, polymers and additives) from the piezometer and stimulate fresh aquifer water representative of the aquifer to the piezometer. Drilling influences were flushed from the bore using air lifting or through introduced fresh water to the borehole. Additional volumes of groundwater were purged using either a manual bailor or a 12-volt Twister groundwater pump, which was completed prior to sampling for water-quality analysis. Multiple groundwater bore volumes were removed from each standpipe piezometer to stimulate flow of ambient groundwater toward the standpipe.

Field parameters for groundwater quality were monitored during development and purging to quantify when drilling influences were removed from the piezometer and groundwater representative of the aquifer was being purged. The standpipe piezometer was considered developed when purge water was free of sediment or field parameters had stabilised over subsequent readings.

Bore completion is summarised in Table 14.14.

TABLE 14.14 SITE INVESTIGATION PROPOSAL MONITORING BORES

Location	Latitude (GDA94)	Longitude (GDA94)	Well depth (mbgl)	Screened interval (mbgl)	Screened lithology[1]	Static Water Level (mbgl)	Static Water Level (mAHD)	Mean hydraulic conductivity, K (m/day)[2]	Aquifer
270-01-BH2201	-28.8711	150.4020	20.0	14 to 20	SILT	Dry	Dry	No analysed[3]	Kumbarilla Beds
270-01-BH2202	-28.8483	150.4042	20.45	8.5 to 17.5	CLAY	17.5	218.87	Not analysed	Kumbarilla Beds
270-01-BH2204	-28.7447	150.4167	20.45	8.5 to 20.5	Clayey SAND/CLAY	10.3	213.22	Not analysed[4]	Undifferentiated sedimentary rock
270-01-BH2206	-28.7056	150.4153	20	8.7 to 14.7	Sand/Gravel	11.26	213.54	0.01	Alluvium
270-01-BH2212	-28.6669	150.4526	23.2	11.2 to 23.2	Sandy CLAY/SAND	9.6	215.91	0.81	Alluvium
270-01-BH2213	-28.6645	150.4533	20	13.5 to 19.5	Sandy GRAVEL/SAND	11.91	215.09	0.19	Alluvium
270-01-BH2217	-28.6459	150.4590	20	9.2 to 15.2	Clayey GRAVEL/Sandy GRAVEL	12.3	215.3	0.42	Alluvium
270-01-BH2218	-28.6288	150.4538	20.45	8.8 to 14.8	Clayey Gravel/Gravelly SAND	11.99	213.71	0.16	Alluvium
GW965240	-28.8127	150.4130	12	Landowner bores					
RN30765	-28.6501	150.4939	60						
Robs' Bore	-28.6637	150.4391	20						

Table notes:
SWL = Static Water Level
SWL measured on 3 to 4 October 2018
1. Inferred from bore logs
2. Mean value derived from falling and rising head tests
3. Bore 270-01-BH2201 not analysed as bore was dry
4. Bore 270-01-BH2204 not analysed as bore had not been fully recovered after development

14.5.2 Permeability testing

In-situ hydraulic testing using variable head-test techniques was conducted at six newly installed standpipe bores. The variable head tests involve inducing a sudden change in the groundwater level within the bore casing by inserting (falling-head test mode) and then removing (rising-head test mode) a solid slug or by sudden displacement of the water column in the casing using a pneumatic slug (compressed gas) and then measuring the water level response using an automated pressure transducer water level logger to obtain continuous water level measurements during the test and monitor how long it takes for the static water level (SWL) to recover to its original level.

The SWL was recorded before the slug was inserted in each bore. The hydraulic head (water level) was monitored until it returned (decreased) to within 90 per cent of the SWL, or when sufficient data was deemed to be collected at slow-recovering bores. The automated measurements were confirmed by comparing manual measurements collected using a water level meter. The objective of a hydraulic test is to estimate horizontal hydraulic conductivity (K) of a water saturated rock or soil formation intersected by the screen segment of the bore.

Slug test data was analysed using AQTESOLV Pro 4.0, which is an industry-standard program widely used in the field of hydrogeology for hydraulic parameter estimation. The hydraulic test data was analysed by using the Hvorslev (1951) and KGS (Hyder et al., 1994) solution methods. Hydraulic conductivity is reported in metres per day (m/day) and is a measurement of how easily water can move through pore spaces in a geological formation.

Hydraulic conductivity at each bore is summarised in Table 14.14.

14.5.3 Groundwater level monitoring

A dedicated automatic pressure transducer was installed in each standpipe piezometer for continuous groundwater level monitoring. The pressure transducers installed are In-Situ Rugged Trolls, which were installed at depths ranging between 9 m to 30 m. The transducers record total pressure on the sensor (water column above the sensor and atmospheric/barometric pressure), which is then converted to a groundwater level. Measurements are recorded at one-hour intervals and were calibrated by manual SWL measurements.

Groundwater level at each bore is summarised in Table 14.14.

14.5.4 Groundwater sampling

One round of groundwater sampling was conducted in accordance with AS/NZ 5667.1:1998 and AS/NZ 5667.11:1998 after completion of all standpipe bores for laboratory analyses. The sampling was conducted after completion of bore development; well purging was conducted using Super Twister pump, manual bailing, or both methods. Groundwater samples were collected in laboratory provided containers and shipped in a cooler box chilled with ice under Chain of Custody to ALS Laboratory in Brisbane (a NATA-accredited laboratory).

Samples were collected to provide quantitative data on groundwater chemistry, durability and/or salinity parameters. In total, seven groundwater samples were collected from standpipe bores on 7 October 2018 (270-01-BH2201 was dry during the sampling event and was not sampled). Field quality assurance and quality control (QA/QC) samples were collected during sampling, along with field physiochemical measurements at the time of sampling. Quality control samples were collected to check that the samples were of acceptable quality to make decisions about water quality at the site. Quality control samples provide information that clarifies potential data errors attributable to cross contamination, inconsistencies in sampling and analytical issues.

The following parameters were analysed for each groundwater sample:

- Major anions and cations (calcium, magnesium, sodium, potassium, chloride, fluoride, sulfate)
- Carbonate and bicarbonate alkalinity and hardness
- pH, EC and TDS
- Total and dissolved metals (arsenic, boron, beryllium, cadmium, chromium, cobalt, copper, manganese, iron, nickel, lead, selenium, vanadium, zinc and mercury)
- Nutrients (nitrate, nitrite, ammonia, total nitrogen, Total Kjeldahl Nitrogen (TKN) total phosphorus)
- Sodium adsorption ratio
- Hydrocarbons (phenols—standard level—12 analytes, TPH/TRH (C6-C36 or 40)/BTEX plus VOC)
- Pesticides (OC pesticides—standard level—21 analytes).

14.5.5 Summary of field investigations

A summary of key hydrogeological results is provided for each bore in Table 14.14, including the screened interval depths, the screened lithology, water levels and slug-test results. Three landowner bores were included in the groundwater sampling round in October 2018; however, no water levels were measured, and no slug tests were completed in these bores. The proposal monitoring wells and bore locations are presented on Figure 14.2.

14.6 Conceptual groundwater model

A conceptual model of the hydrogeological regime across the proposal site is presented on Figure 14.7 and summarised below. A water balance for groundwater and surface water is a SEAR (Item 19.2, Table 14.1). The purpose of a water balance, and associated models, is to understand the impact of the take or release of water (surface or groundwater) as a result of a project. That is, to describe the flow of water in and out of a system (water budget). A water balance for the proposal is not considered warranted as there are no significant cuts, tunnels, or other structural components that result as water take (temporary construction dewatering is not applicable for water balance) from, or water discharge to, the water budget.

Hydraulic models were developed as a component of the hydrology and flooding study, in Appendix H: Hydrology and Flooding Technical Report, to understand the localised catchment inflows and runoff to understand flood conditions; however, as no water requirements (take or release to the water budget) are anticipated after the construction phase of the proposal, no water take/release is anticipated and, therefore, a water balance is not warranted.

Unconsolidated Cenozoic-aged alluvium characterises the northern half of the alignment and has been deposited as continuous alluvial channels, paleo channels and alluvial fans from the Macintyre and Severn river systems. Cenozoic alluvium represents all alluvium encountered within and surrounding the proposal. In Figure 14.7, alluvium is represented by the yellow upper unit in the northern half of the proposal and as less extensive units further south. This Cenozoic alluvium is typically 20–60 m thick and overlies the Wallumbilla Formation (a recognised regional aquitard) and Kumbarilla Beds (Surat Basin units). Registered bore and site-investigation bore lithological descriptions indicate that the upper 5–10 m of the alluvium is dominated by fine-grained alluvium (clays and sandy clays). The primary aquifers of the Cenozoic alluvium are the coarser grained sand and gravelly sand units of variable thickness. The Cenozoic alluvium also forms localised aquifer systems along ephemeral watercourses that include Mobbindry Creek, Back Creek, Forest Creek and Whalan Creek.

Groundwater levels in the Cenozoic alluvium typically range from 7–20 mbgl with regional groundwater flow to the north-northwest (lateral flow mimicking topography and surface water flow). Topography plays a marked role with regards to local groundwater flow direction in the alluvial aquifers (i.e. a water table influenced by elevation).

Groundwater has been encountered at shallower depths (4–6 mbgl) in localised Cenozoic alluvium in ephemeral creek systems in the southern portion of the proposal site. Long-term (natural) variation in groundwater levels in the alluvium are typically in the range of 1 m during major rainfall events. Yields for the alluvium typically range from 1 to 4.5 L/s.

Based on available registered bore and site investigation data, the Kumbarilla Beds are typically intersected at 10 to 50 mbgl in the southern portion of the alignment and at greater depths in the northern portion of the alignment (100 to 200 mbgl). The upper portion of the unit characterised by highly weathered shales that yield high-salinity groundwater (i.e. BH2202). Groundwater flow based on registered bore data is generally to the north. The Kumbarilla Bed aquifers are confined by overlying shale of the Wallumbilla Formation with bore yields typically <2 L/s.

The Walloon Coal Measures underlie the Kumbarilla Beds where the water-bearing zone is typically intersected over 300 mbgl in the proposal site. These coal measures are characterised by shales, sandstones and coal seams that host confined aquifers that, in some instances in the groundwater study area, are free flowing (artesian). Bore yields are typically higher in the Walloon Coal Measures and range from 7–9 L/s based on limited data from registered bores near the alignment.

14.6.1 Recharge

The natural creeks along the proposal site form losing systems that act to recharge the underlying alluvial sediments seasonally when flowing (during and immediately after the wet season). Recharge to alluvium that is hydraulically connected to the Macintyre River is subject to artificial recharge from the regulated river system, which maintains permanent flow from upstream impoundments. Additional recharge mechanisms of the alluvium include direct infiltration from rainfall and irrigation (deep drainage).

The alluvium may provide a level of recharge to the underlying Kumbarilla Beds aquifer, where deep palaeochannels and faults provide hydraulic connection, as the Wallumbilla Formation is considered limited in vertical extent in such areas.

14.6.2 Discharge

Hydrographs from registered bores in the Cenozoic alluvium surrounding the proposal demonstrate a strong hydraulic connection to surface water. The alluvial aquifers are recognised to discharge through vertical flow, as well as through evapotranspiration.

Registered bores that intersect the alluvial aquifers near the proposal site demonstrate a wide variety of use, including domestic and industrial use, irrigation and water supply.

Based on registered bore data and water-licence allocations, water use from the Kumbarilla Beds and Walloon Coal Measures is typically for stock watering and, to a lesser extent, irrigation.

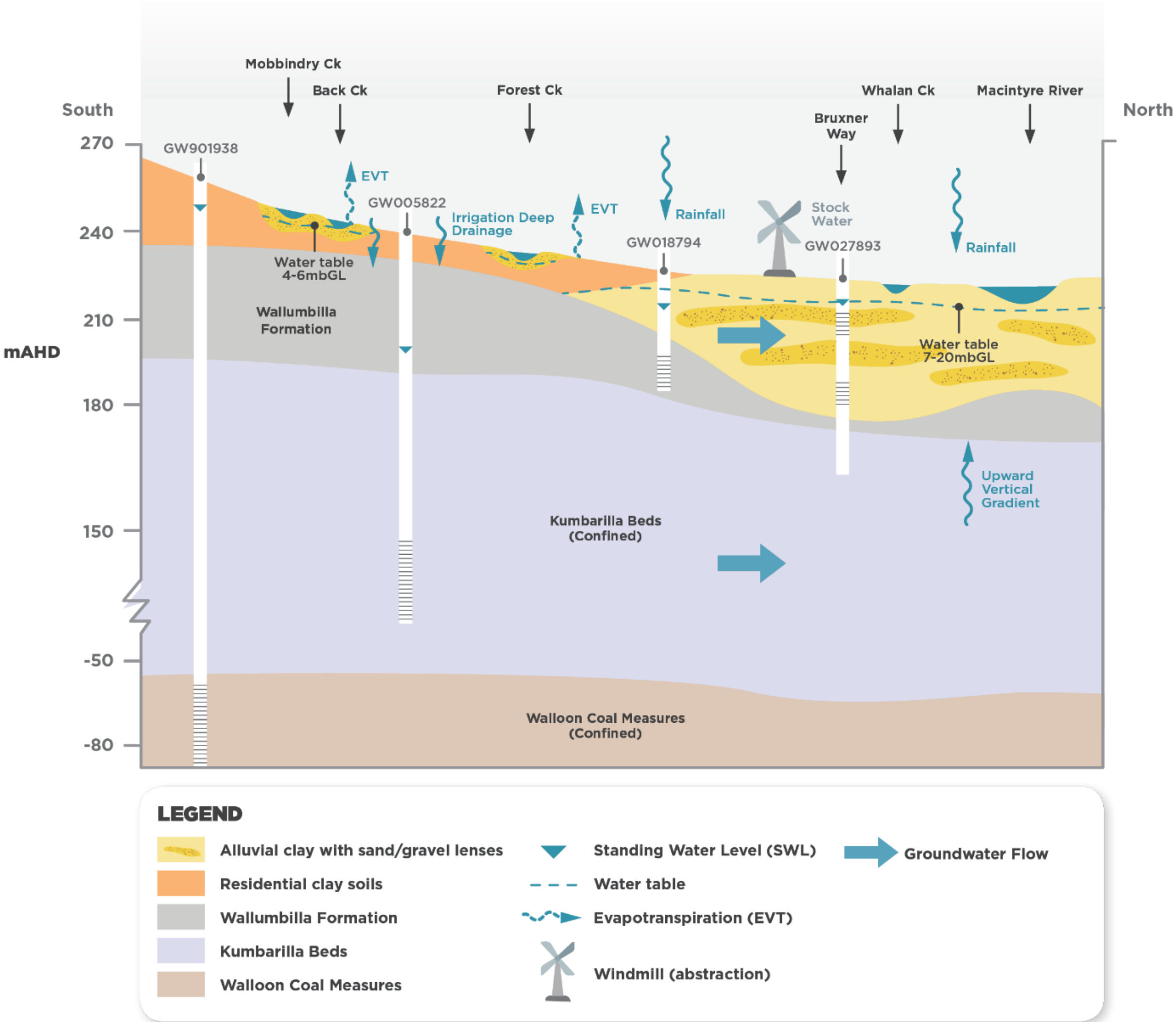


FIGURE 14.7 CONCEPTUAL HYDROGEOLOGICAL MODEL FOR THE PROPOSAL

14.7 Potential impacts

14.7.1 Construction activities

Construction of the proposal will involve a combination of earthworks, including cuts and embankments (to ensure required grade for trains), bridges and borrow pits to supply fill and aggregate for construction. The proposed construction methods for the alignment and the key assumptions for each method are in Table 14.15.

TABLE 14.15 SUMMARY OF CONSTRUCTION METHODS AND ASSUMPTIONS

Method	Description	Assumptions
Embankments	Volumes of material emplaced and compacted to raise the profile of the railway alignment to meet design specifications	No embankments are proposed over 10 m in height No dewatering (possible alteration of shallow groundwater) is anticipated Compaction may occur as part of the embankment construction works
Cuts	Removal of soil and rock to maintain the grade of the alignment design Stripping of topsoils of approximately 0.3 m below existing ground level is expected beneath most sections of earthworks	The maximum cutting depth is 2.3 m
Bridge and pilings	A total of 11 rail bridges are proposed to cross roads and waterways. Cast-in-place pilings to be emplaced on each bridge. A 1.8 km long viaduct is proposed over the Macintyre River and Whalan Creek. Some cast-in-place pilings may be substituted with driven pilings in the detailed designs.	Pilings currently proposed with a span width of 14 to 33 m and depth ranging from 8–43.5 mbgl. All piling designs are founded in soil and alluvium; no bedrock is to be intersected.
Borrow pits	Shallow excavations at key designated locations near the proposal alignment to source soil, sand and gravel. The proposal is considering 11 potential borrow pit locations.	Depth of excavation typically less than 3.0 mbgl except for two pits located within Tertiary basalt (discussed further in Section 14.7.1.7)

The location of proposed structures along the alignment are presented in Table 14.16.

TABLE 14.16 SUMMARY OF PROPOSED STRUCTURES AND ESTIMATED GROUNDWATER LEVEL

Type	Structure ID	Start chainage (m)	End chainage (m)	Median surface elevation (mAHD)[1]	Median estimated water level (mAHD)[2]	Median estimated water level (mbgl)[2]
Cut[3]	270-C1	11230	11420	239	189	51
Bridge	270-BR01	5703	5815	242	184	58
Bridge	270-BR02	6136	6318	242	184	58
Bridge	270-BR03	8063	8133	236	194	42
Bridge	270-BR04	16257	16411	225	214	11
Bridge	270-BR05	20666	20802	225	214	11
Bridge	270-BR06	25240	25400	224	217	8
Bridge	270-BR07	25734	25848	224	217	8
Bridge	270-BR08	25988	26171	224	217	8
Bridge	270-BR09	27498	27624	224	216	8
Bridge	270-BR10	27968	28094	227	211	16
Bridge	270-BR11	29357	31107	226	214	12
Bridge	270-BR12	31437	31577	225	215	10
Bridge	270-BR13	32245	32791	225	215	10

Type	Structure ID	Start chainage (m)	End chainage (m)	Median surface elevation (mAHD)[1]	Median estimated water level (mAHD)[2]	Median estimated water level (mbgl)[2]
Embankment	270-E1	4920	6770	241	185	56
Embankment	270-E2	7290	9340	238	191	47
Embankment	270-E3	9790	11080	237	193	45
Embankment	270-E4	11420	12310	237	192	45
Embankment	270-E5	12310	12540	235	196	39
Embankment	270-E6	13150	15160	230	206	25
Embankment	270-E7	15160	16970	226	214	12
Embankment	270-E8	17690	18320	226	214	12
Embankment	270-E9	19030	19770	224	217	7
Embankment	270-E10	20140	32880	224	216	9
Embankment	270-E11	34480	38830	228	210	17

Table notes:

1. Surface elevation calculated based on cut/fill data provided by FFJV on 11 September 2019
2. Estimated water level calculated using a linear regression line produced using local groundwater data sourced from the National Groundwater Information System (BOM, 2018b), the *Queensland Globe Registered Bore Database* and site investigation data
3. Cut depth is proposed to be <2.3 mbgl

14.7.1.1 Site clearing and grading

Site clearing and grading activities could potentially impact shallow groundwater resources due to:

- Removal of vegetation reducing evapotranspiration, which can influence the groundwater discharge (i.e. result in higher groundwater levels)
- Compaction of ground resulting in reduced groundwater recharge
- Alteration of possible existing areas where ponding surface water occurs naturally, which could reduce groundwater recharge that could occur in these areas.

The limited area to be cleared and graded, compared to the large aquifer extents along the rail alignment, is considered to have little or no impact on the groundwater resources (particularly as the rail corridor follows the existing non-operational Boggabilla rail corridor for most of the proposal site).

14.7.1.2 Piling activities

Piling associated with ground improvement works, to stabilise the bridge areas, is proposed in the north of the alignment. The pilings are to comprise the cast-in-place piling technique with concrete emplaced via a tremmie line or other pumping method. This technique allows for the removal of augured soil/rock while pumping concrete or grout through the hollow stem to stabilise the ground. Future detailed design phases may include substitution of some cast-in-place pilings with driven pilings.

Piles with a diameter of 0.9–1.2 m are proposed for installation on 11 bridges between Ch 5 km and Ch 31 km. The pilings will have span length ranging from 14–33 m and will be installed to depths ranging from 8–43.5 mbgl.

The potential impacts of the piling works on groundwater resources can:

- Alter aquifer parameters (lowering permeability)
- Alter groundwater flow patterns (mounding or drawdown hydraulically up and down-gradient of the piles)
- Reduce groundwater resources through extraction of wet soil/rock during piling.

Consideration of these potential impacts includes:

- The potential impacts of the alteration of the aquifer parameters is considered limited due to the small area of alteration within the saturated sediments compared to the overall alluvium aquifer extent
- The spacing of the piles (non-continuous with regular spacing) does not result in a continuous hydraulic barrier of low permeable grout/cement, so that throughflow in the hydrostratigraphic units intersected by the piles will not be markedly influenced. Therefore, the spacing between the piles is considered sufficient so that mounding (on the upgradient side) or dewatering (due to reducing in the throughflow on the downgradient side of the portal) is not expected to occur.
- The potential reduction in groundwater volumes due to the piling is limited as the cast-in-place augering method, which allows for concrete slurry to be pumped through the hollow stem auger, restricts the amount of groundwater brought to surface
- Based on previous experience, only minor amounts of groundwater (within the wet sediment/soil/rock) will be brought to surface—some 5–10 litres per 20 m deep auger hole. Using the proposed piling methodology will not require active dewatering (using pumps and infrastructure to evacuate groundwater to enable construction works to proceed) and the minor amounts of groundwater (as a slurry with soil/rock) will be managed at each pile/drill site.

14.7.1.3 Cut section

There is one cut section (270-C1) currently proposed along the alignment at approximately Ch 11.34 km to Ch 11.39 km. This cut is anticipated to reach a depth no greater than 2.3 mbgl within the alluvium and is not anticipated to encounter the water table.

14.7.1.4 Embankments

There are seven embankment sections (270-E1 to 270-E7) located between Ch 7.28 km and Ch 30 km. The expected subgrade for all embankments is Quaternary alluvium or colluvium.

14.7.1.5 Bridge and piling sections

The proposed design for the proposal includes 11 bridge sections between Ch 5.7 km to Ch 30 km with structural support from cast-in-place pilings. The expected subgrade for all bridges and piling works is Quaternary alluvium.

14.7.1.6 Construction water

Construction activities

Estimated (preliminary) water requirements for the construction period of the proposal are in Table 14.17. Each construction activity will involve different levels of quantity, quality, and flow rates to achieve the planned construction tasks (refer Table 14.17). The proposal is considering a surface water source near Boggabilla Weir, which may be supplemented by groundwater abstracted from landowner bores with existing water allocation licences.

Groundwater quality indicates it can only be sourced for earthworks and track works; however, groundwater is not the only or preferred source of construction water for the proposal. Sources of construction water will be finalised during the detailed design phase of the proposal (post-EIS) and will be dependent on climatic conditions in the lead up to construction. The hierarchy of preference for accessing of construction water is generally anticipated to be as follows:

- Public surface water storages
- Permanently flowing watercourses
- Privately held water storages
- Existing registered and licensed bores
- Town water.

If groundwater is considered for sourcing construction water, it will be sourced from existing registered and licensed bores. Therefore, the volumes extracted would be within the existing licensing limits and the extent of drawdown experienced would be localised and consistent with that currently permissible for each licensed bore.

Domestic needs will be prioritised above construction water supply and existing sustainable allocated water entitlements will be sourced, where possible.

TABLE 14.17 ESTIMATED WATER REQUIREMENTS AND POTENTIAL WATER SOURCES DURING CONSTRUCTION ACTIVITIES

Activity	Uses/ requirement	Quality	Potential sources[1]	Approximate volume (ML)[1]	Timeframe (duration)
Earthworks	Material conditioning and general dust suppression	Low	River, dam or bore	Conditioning (130 ML)	Mar 2021 to August 2022 (~1 year, 5 months)
				Dust suppression (62 ML)	January 2021 to January 2024 (~3 years)
				Haul road maintenance (49 ML)	April 2021 to January 2024 (~2 years, 9 months)
Construction camp	Drinking water, showers, toilets, washing and cooking facilities	High	Town supply and water harvesting	1 ML of water per month	To be determined
Concrete	Bridge and culvert locations	High	NA (no concrete batch plant provision for proposal, local concrete suppliers may be engaged)	NA	To be determined
Track works	Ballast dust suppression during ballasting and regulating activities	Low	River, dam or bore	0.36 ML	July 2023 to June 2024 (~11 months)

Table note:
1. Potential water sources and estimated (indicative) volumes are preliminary only

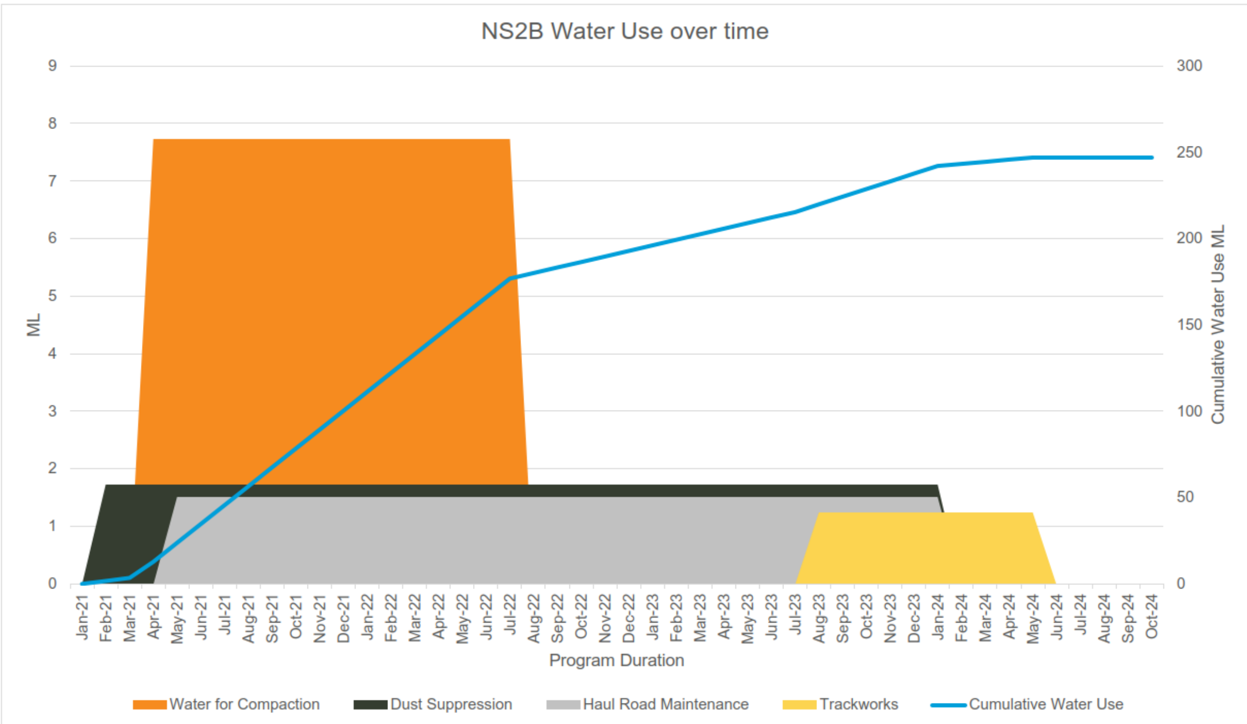


FIGURE 14.8 TIMELINE OF ESTIMATED WATER USE FOR THE PROPOSAL

As shown in Figure 14.8, the greatest water demand will occur in the first year of construction where water use for conditioning, dust suppression and haul road maintenance overlap.

Construction camp water supply

One construction camp is currently proposed off North Star Road and Wilby Street in North Star. The camp will require an estimated 1 megalitre (ML) of water per month of operation. The township of North Star currently has access to water through an existing allocation, with approximately 40 ML per year of available groundwater under the current Water Sharing Plan (ceased July 2018); the construction camp is likely to use the North Star town water supply (refer Table 14.18 for bore information).

To reduce reliance on the North Star town water supply, a rainwater harvesting system will be implemented, where practical. A greywater recycling system should also be explored to reuse water for activities such as toilet flushing. All potable water supplies on the proposal should comply with the *Australian Drinking Water Guidelines* (NHMRC, 2011).

TABLE 14.18 NORTH STAR WATER SUPPLY BORE SUMMARY

Bore ID	Yield (L/sec)	Latitude	Longitude	Comments
GW009991	8.84	-28.9279	150.3945	Water supply bore in North Star

Wastewater produced from the construction camp will be treated by using an experienced and accredited supplier of commercial sewerage treatment systems. These systems can be designed for the capacity required in the construction camp and could remain in position for handover to the local township once the construction camp is decommissioned. The second alternative is to connect directly to the North Star municipal system; however, this system is nearing capacity and upgrades would have to be undertaken by the proposal.

14.7.1.7 Borrow pits

A total of 11 potential borrow pit locations have been identified for the proposal to supply general fill, structural fill, ballast and/or capping. The proposed borrow pits are summarised in Table 14.19. The proximity of the borrow pits range from within the proposal area to up to 18 km from the alignment. A desktop assessment and geotechnical review were completed in early 2019 to evaluate the feasibility of each potential location. These recent works included site inspections to confirm the geology and suitability of material present in each borrow pit.

The location of the 11 borrow pits were reviewed in the context of the geological (i.e. alluvium versus Surat Basin strata) and the hydrogeological conditions (i.e. typical groundwater levels) discussed in Sections 14.4.1 and 14.4.3.

Apart from borrow pit Site 1 and Site 2, which are located within Tertiary Basalts, the maximum depth of excavation anticipated for the potential pits is 3.0 m. Most borrow pits are interpreted to be developed in weathered sedimentary rocks of the Kumbarilla Beds and/or the Wallumbilla Formation. Based on registered bore and site investigation data, the first water-bearing zone intersected during drilling has been used to evaluate the potential to encounter shallow groundwater for each borrow pit.

Based on this data, shallow groundwater is unlikely to be intersected at borrow pits located in the Kumbarilla Beds or the Wallumbilla Formation. Despite the deeper potential excavation depths at Site 1 and Site 2 (up to 24 m), shallow groundwater is also unlikely to be intersected. Further details with respect to borrow pit excavation depths and potential for groundwater interaction are discussed in Appendix N: Groundwater Technical Report.

14.7.2 Construction—potential impacts

Construction activities for the proposal include a variety of activities that have the potential to impact on groundwater resources. These activities include earthworks (cut and fill sections), drainage construction, haul road and access track construction, track laying, bridge pilings and the excavation of borrow pits for construction materials.

14.7.2.1 Subsidence/consolidation

Only one cut is proposed (Ch 11.3 km) and the toe of the cut will be well above the inferred water table. The location of proposed structures along the alignment are shown in Table 14.16.

Pilings are not anticipated to require significant dewatering, due to the cast-in-place construction method. Subsidence issues are unlikely to occur given that construction dewatering will be limited and not prolonged in nature.

Compaction could alter antecedent aquifer properties in the alluvium due to embankment construction; however, the risk is considered low given the water table is well below the existing ground surface at the proposed embankment sections (>8 mbgl).

TABLE 14.19 BORROW PIT SUMMARY

Borrow pit	Approximate distance from rail alignment (m)	Estimated resource thickness (m)	Formation	Material description	Estimated regional groundwater level (mbgl)	Nearest bores reporting depth of water strike (mbgl)	Potential for groundwater intersection
4	3,000	3.0	Kumbarilla Beds	Lateritised siltstone and sandstone	> 15	BH2201 (Dry) and BH2202 (17.5m) GW000740: 1.8km to S (water strike @ 57 .9m)	Unlikely
5	10,300	2.5	Kumbarilla Beds	Weakly lateritised sedimentary rock	> 50	GW006151: 1km to NW (water strike @ 121.9m) GW006238: 1.7km to E (water strike @ 55.8m)	Unlikely
8	730	3.0	Kumbarilla Beds	Lateritised siltstone and sandstone	> 20	BH2203 (Dry) GW005173: 0.5km to E (water strike @ 39.6m)	Unlikely
9	14,300	3.0	Kumbarilla Beds	Lateritised siltstone and sandstone	> 40	GW007410: 1.2km to E (water strike @ 43.6m) GW007518: 2.5km to S (water strike @ 58.8m)	Unlikely
11	16,000	2.0	Kumbarilla Beds	Ferruginous caprock underlain by clayey sand	> 15	GW007518: 2.5km to S (water strike @ 58.8m) GW965235: 0.8km to S (slotted interval @ 19.3 to 20.3) GW00613: 1.5km to SW (water strike @ 160.9m)	Unlikely
13	14,000	2.0	Wallumbilla Beds	Highly weathered sedimentary rock	> 40	GW031554: 1.3km to SE (water strike @ 171.9m) GW000502: 2.8km to sth (water strike @ 45.7m)	Unlikely
25	12,500	3.0	Kumbarilla Beds	Lateritised siltstone and sandstone	> 50	GW005591: 0.7km to E (water strike @ 94.5m) GW000638: 1km to W (water strike @ 71.6m)	Unlikely
26	10,000	2.0	Kumbarilla Beds	Extremely weathered sandy clay	> 50	GW006238: 2.0km to SE (water strike @ 55.8m) GW025529: 3km to W (water strike @ 162.8)	Unlikely
7 and 7b	Within study area	3.0	Kumbarilla Beds	Sandy clay and weathered siltstone and sandstone	> 15	BH2202 (17.5m) GW018995: 2km to S (water strike at 76.2m) GW049209: 0.7km to N (water strike @ 138.4m)	Unlikely
1	8,000	12.5	Tertiary Basalt	Moderate to slightly weathered basalt	> 40	GW018899: 0.3km to S (water strike @ 59.13m) GW006281: 3km to S (water strike at 45.7m)	Unlikely
2	11,500	24.0	Tertiary Basalt	Moderate to slightly weathered basalt Located on an elevated area 15 m above surrounding land surface	>40	GW011114: 0.8km to E (water strike @ 50.3m) GW000856: 0.8km to SE (water strike @ 112.7m)	Unlikely

14.7.2.2 Groundwater levels

There are potential impacts to groundwater levels in the shallow alluvial aquifers from earthworks, cuttings and bridge piling works if temporary dewatering was to occur during construction (i.e. potential decrease in levels); however, the likelihood of any significant dewatering occurring is expected to be minimal (and likely passive dewatering) given:

- Groundwater infiltration into foundation boreholes, cuttings or other earthworks will be limited given the depth to the water table is typically 7–20 mbgl
- No active dewatering (pumping) is anticipated at piling locations given only minor volumes of groundwater will be brought to surface, some 5–10 litres per 20 m in auger holes using the Cast-in-place method. This volume of water would be managed at each site.
- The construction works are limited in duration so, consequently, any dewatering will also be restricted in duration (temporary).

Potential adverse impacts to groundwater levels may occur where groundwater is sourced to supply water for construction activities. Over-abstraction from an existing bore with a shared or purchased water entitlement may reduce water levels and, in turn, reduce availability to other users. Other water sources are being considered to contribute to the supply of construction water (i.e. rainfall harvesting, farm dams and water recycling).

If a portion of the construction supply water is obtained from groundwater, short-term, localised impacts on shallow groundwater are expected, with no significant impacts on groundwater resources, groundwater quality or downstream users. Licensing to take water is likely to be required to meet requirements under the relevant Water Sharing Plans and will require consultation with the National Resource Access Regulator.

Mitigation measures to minimise impacts on groundwater levels during the construction phase are provided in Section 14.8.

14.7.2.3 Groundwater flow

Potential impacts on groundwater flow within the alluvial aquifers are expected to be minimal, due to:

- Shallow depth of the proposed cuts along the alignment (<2.3 mbgl) is unlikely to create voids that intersect shallow groundwater or perturb the antecedent groundwater flow regime
- Foundation pilings associated with bridges are of a sufficient spacing and diameter to result in minimal impact on existing groundwater flow
- Reduction of permeability of natural soils beneath constructed embankments may alter the flow direction of shallow groundwater in the Alluvium aquifer.

The mitigation measures detailed in Section 14.8 are proposed where the depth of a cut or borrow pit has a perceived risk of intersecting shallow groundwater.

14.7.2.4 Groundwater dependent ecosystems

High-potential aquatic GDEs were identified over 1 km from the proposed alignment at Malgarai Lagoon and in an upstream portion of the Macintyre River. High-potential terrestrial GDEs were identified in several of the ephemeral waterbodies crossed by the proposal (refer Section 14.4.7). Proposal activities are not anticipated to affect shallow groundwater near these high-priority GDEs given their distance from the alignment and/or the fact that construction works are not anticipated to intersect groundwater.

Given the limited expected impact on groundwater levels (refer Section 14.7.2.2), there is likely to be no adverse impacts on high-potential terrestrial GDEs identified in Section 14.4.7 (refer Table 14.9 and Table 14.10).

14.7.2.5 Groundwater users

No impacts are anticipated to the accessibility of groundwater for stock watering, irrigation and farm use during construction of the proposal.

Potential impacts may arise due to cuts that intersect shallow aquifers resulting in a net loss in groundwater supply to impacted receptors. Sensitive receptors may include users in the vicinity of perennial water bodies or near shallow water supply bores such as the alluvium associated with Mobbindry Creek, Whalan Creek and Macintyre River system. The proposed depth of the cut at Ch 11.3 km is not expected to intersect the groundwater table and, therefore, this impact on users is expected to be minimal.

Other impacts to users may include contaminants entering shallow aquifers and hydraulically connected surface water bodies and impacts on groundwater levels if bores are used to supply construction water (discussed further in Section 14.7.2.6).

Groundwater users may potentially be impacted if groundwater abstraction from landowner bores takes place to supplement water supplies for construction works; however, any abstraction for the proposal would be via the sharing or purchase of an existing water licence, which already has annual abstraction limits assigned by regulatory authorities to negate adverse impacts.

14.7.2.6 Contamination

During the construction phase, potential sources of contamination to groundwater are likely to occur from:

- Accidental spills and leaks of hydrocarbons (oils, fuels and lubricants) and other chemical associated with plant and equipment
- Water mixtures and emulsions related to washdown areas
- Wastewater from the construction accommodation
- Upward leakage along piles/soil interfaces of saltier groundwater from the deeper confined aquifers into the fresher alluvial aquifer.

Direct infiltration of contaminants through the ground surface to the shallow aquifers will be limited due to the low permeability of clayey soils present in the upper 2 m of the soil profile across much of the alignment and that the depth to groundwater in this unit is typically > 7 mbgl.

Base on publicly available data on soil types near North Star, direct infiltration of treated wastewater from the construction accommodation may be limited due to stiff clay/silty clay sodosol soils, which could create ponding and surface water runoff issues. Pooling or runoff of such water may pose a risk to humans and stock in the surrounding area.

The ephemeral nature of the majority of surface water bodies along the alignment is also likely to reduce the chance of contaminants in surface water infiltrating into shallow aquifers.

Potential contamination of the shallow alluvial aquifer could occur via inflow into foundation boreholes that intersect the water table. This is not considered likely as pilings will be grouted to surface for ground stability; therefore, they are not anticipated to act as a conduit for surface contaminants to impact on groundwater resources.

14.7.2.7 Vegetation and soil removal (salinity)

Clearing of deep-rooted vegetation may increase infiltration rates into shallow aquifers and lead to a rising groundwater table and possibly elevated soil salinity (Schofield and Scott, 1991). Based on the low density of deep-rooted trees within the alignment, the impact of tree removal on soil salinity is not expected to increase salinity within the proposed rail corridor.

The seasonal nature of rainfall also reduces the proportion of time salinity issues can eventuate from a rising water table.

14.7.2.8 Acid rock drainage and acid sulfate soils

The intersection of sulfide-bearing rocks in cuts or use of sulfide-bearing materials in embankment fill could present an acid rock drainage (ARD) risk following exposure of the rocks to oxygen and subsequent runoff, which could impact on environmental values, aquatic GDEs and groundwater users. ARD occurs naturally when sulfide minerals are exposed to air and water. This process is accelerated through excavation activities, which increase rock exposure to air, water, and microorganisms. The resulting drainage (leachate) may be neutral-to-acidic, with dissolved heavy metals and significant sulfate levels. Potential acid sulfate soils (PASS) also present a risk though excavation of cuts in soils susceptible to acid-forming conditions, which can leach into the surrounding environment.

PASS is often associated with low-lying areas below 5 mAHD, such as alluvial plains where groundwater is generally close to the surface and materials in reducing condition along coastal regions (Department of Science, Information Technology, Innovation and the Arts (DSITIA) Qld, 2014); however, the lowest elevation of the Project is 223 mAHD.

There are no deep cuts in the proposal and the shallow cuts (less than 2.3 m deep) are anticipated to encounter the Kumbarilla Beds, which is a sedimentary sequence (comprising sandstone, siltstone and mudstone). Assessment of PASS within the groundwater study area using the *Atlas of Australian Acid Sulfate Soils* map (CSIRO, 2014) indicates low probability of PASS occurring between North Star and the alignment west of Humptybung, and extremely low probability of PASS occurring for the remaining study area.

No indicators of PASS and, as a result, ARD were observed; however, in the event PASS is present and results in ARD during the construction phase of the proposal, mitigation measures will be undertaken as listed in Table 14.21.

14.7.3 Operation—potential impacts

There is a potential for increased groundwater levels due to surface loading of alluvial soils from embankments and other construction along the alignment where groundwater is shallow. Potential areas for compressible alluvial soils include localised portions of the low-lying Macintyre floodplain associated with abandoned river channels. However, it is expected that these impacts will be localised due to the linear nature of the alignment and the depth to groundwater typically being > 7 mbgl.

Potential impacts on groundwater quality from the operation stage of the proposal can result from spills and leaks from normal operational activities and maintenance. These impacts are likely to be superficial and not expected to impact on shallow aquifers.

14.8 Mitigation measures

A Construction Environmental Management Plan (CEMP) will be prepared during the detailed design process (post-EIS) to capture all mitigation measures required to be implemented before or during construction of the proposal. An Operation Environmental Management Plan (OEMP) is envisaged to be developed during construction to identify management and mitigation measures to be implemented or adhered to for the operation phase of the proposal.

The Environmental Management Plan (EMP) in Chapter 27: Environmental Management Plan will be used as a basis for the CEMP; the Groundwater Management and Monitoring Plan (GMMP) (refer Section 14.8.3) will inform the groundwater aspects of the CEMP and OEMP as a groundwater sub-plan.

At feasibility stage of the proposal, the mitigation measures (design and proposed) should demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm have been investigated and proposed to be implemented.

14.8.1 Design considerations

The mitigation measures and controls presented in Table 14.20 have been factored into the reference design of the proposal. These design considerations are proposed to minimise the environmental impacts of the proposal and therefore contribute to a lowering of the initial impact significance rating for each potential impact.

TABLE 14.20 INITIAL MITIGATIONS OF RELEVANCE TO GROUNDWATER

Aspect	Initial mitigations
Water resources	The proposal is generally located within the existing non-operational Boggabilla rail corridor and has been aligned to be co-located with existing road infrastructure, where possible, minimising the need to develop land and impact on water resources that have not previously been subject to disturbance for transport infrastructure. The alignment (both lateral and vertical) has been designed to minimise earthworks, reducing the potential to impact water resources (for example dewatering of cuttings and embankment placement). Culverts and embankment construction are designed to minimise pre-loading and compaction of alluvial sediments. This approach will reduce the risk of altering shallow groundwater levels and recharge patterns. The current embankment designs allow for openings (i.e. culverts and bridge spans) near creeks and rivers to assist with flow. There is likely to be minimal impact to groundwater as a result of loading due to the comparatively small linear area involved and the depth to the alluvium aquifer, typically >7 mbgl. Permanent drainage structures (pre-cast concrete pipe products) will be installed in areas where there are significant sections of embankment fill that incorporate significant cross drainage structures over floodplain areas.
Water quality	Maintenance activities, refuelling, and other tasks with potential for spills or releases to the ground surface will be carried out within the proposal footprint and at a minimum of 50 m from surface water bodies and other sensitive receptors (surface water features). In the event of a spill, the risk of impacting on shallow groundwater is reduced. Clearing extents are limited to that required to construct the works and associated environmental management controls.

14.8.2 Proposed mitigation measures

To manage and mitigate proposal impacts, several mitigation measures have been proposed for implementing in future phases of proposal delivery. These proposed mitigation measures have been identified to address proposal-specific issues and opportunities, including legislative requirements and accepted government plans, policy and practices.

Table 14.21 identifies the relevant proposal phase, the aspect to be managed and the proposed mitigation measure. The mitigations presented in Table 14.21 have been factored into the assessment of residual significance, as documented in Table 14.23.

These proposed mitigation measures are presented in the GMMP, discussed in Section 14.8.3, will be a subplan to the EMP and/or CEMP and OEMP in accordance with the proposal phase they will be implemented in:

- Detailed design
- Pre-construction
- Construction
- Operation.

Further details about the measures in Table 14.21 are included in Appendix N: Groundwater Technical Report.

TABLE 14.21 PROPOSED GROUNDWATER MITIGATION MEASURES

Delivery phase	Potential impacts	Mitigation measures
Detailed design	Water resources	Further assessment of design concepts at watercourse crossings to minimise embankment loading or compaction of alluvial sediments and mounding of groundwater levels (i.e. use of pilings). Assessment of sizing for longitudinal drainage for permanent drainage features. Define requirements for construction water (volumes, quality, demand curves, approvals requirements and lead times), storage locations along the construction footprint, e.g. water used for dust suppression will not result in adverse environmental or health impacts. Continue collection of baseline/pre-construction groundwater monitoring data (levels and quality) to ensure robust dataset for characterisation of the primary aquifers of relevance over a time sufficient to identify seasonal variation trends. Confirm groundwater allocations available per aquifer at cut areas that expect passive dewatering to ensure this approach is suitable. Seepage prevention measures will be investigated through the detailed design process for inclusion in the design, as appropriate.
	Water quality	Site inspections of proposed cut locations will be conducted to visually examine surface outcrops for sulfide minerals or remnant products indicative of sulfide mineralisation. This would inform the need for management of potential ARD from cuttings in sedimentary units prior to construction works. Further assessment of potential borrow pit areas to confirm quality of material (e.g. not contaminated or ARD potential areas). Continue collection of baseline/pre-construction groundwater monitoring data (levels and quality) to ensure robust and comprehensive dataset for characterisation of the primary aquifers of relevance over time sufficient to identify seasonal variation trends. The baseline monitoring program will act as an early mitigation measure, as the data collection will be incorporated into the GMMP for subsequent proposal stages to enable assessment for other aspects of impact assessment/ mitigation.
Pre-construction	Water resources	Confirm (i.e. physical survey/'ground truth') the location of registered bores that may be lost due to construction or operation of the proposal and engage with licensed user to determine mitigation strategy (for example replacement of water supply, if required). Undertake bore survey/census to identify any potential unregistered bores (landowners) that may be impacted by the proposal. Confirm sources for construction water requirements (surface water, groundwater, municipal supply, etc.) via consultation with relevant stakeholders (including landowners/occupants) prior to construction and appropriate approvals and agreements will be sought for the extraction of water. Where private water sources are used for construction, monitoring will be undertaken during extraction to ensure volumes and conditions stipulated by licence requirements and/or private landowner agreements are met. Environmental management requirements (e.g. WQOs) during construction are identified through appropriate baseline groundwater monitoring. Continue collection of pre-construction/baseline groundwater data (levels and quality) to ensure robust and comprehensive dataset to be incorporated into the construction GMMP, discussed further in Section 14.8.3. Where practical, vegetation clearing and ground disturbing works will be staged sequentially across the proposal to minimise areas exposed to erosion and sediment impacts.

Delivery phase	Potential impacts	Mitigation measures
Pre-construction	Water quality	Site inspections prior to the construction of cuts would provide an opportunity to visually examine surface outcrop for sulfide minerals or remnant products indicative of sulfide mineralisation. This would inform the management of potential ARD cuttings in the sedimentary units before construction works. Identification of contaminated, hazardous or potentially contaminated material onsite (i.e. soil, ballast) will be subject to a risk assessment and managed in accordance with any relevant applicable legislation and regulations. The reuse or retention of contaminated or potentially contaminated material on site (i.e. soil, ballast) will be managed by a suitably qualified person, where required.
Construction	Water resources	Environmental management requirements and project commitments during construction to minimise potential impacts such as adverse effects on groundwater users and sensitive receptors (i.e. bores and potential GDEs) are implemented as per resource agreements. Permanent drainage structures (pre-cast concrete pipe products) will be installed in areas where there are significant sections of embankment fill that incorporate significant cross drainage structures over floodplain areas. Implementation and adherence to the CEMP and GMMP with appropriate groundwater level and quality monitoring criterion based on the baseline groundwater monitoring, modelling, analysis, and regulatory requirements to minimise impacts to groundwater resources (e.g. regular groundwater monitoring) and enter into make-good arrangements with the owners of the groundwater bores as necessary. Construction-phase GMMP implemented and adhered to. Opportunities to re-use/recycle construction water are identified and implemented, where feasible, during construction.
	Water quality	Personnel involved in ground-disturbing works are familiar with the unexpected finds protocol/procedure and people onsite will be trained in the identification of potential contaminated soil/material and the relevant controls that will be put in place in the event of its discovery. This includes: ▶ How to recognise potential contaminated material (colour, texture, odour, presence of asbestos, metal, ash) from inert waste or materials ▶ The correct use of spill kits ▶ Stop work and corrective/containment actions ▶ Classification and notification of incidents in accordance with the ARTC incident management procedure ▶ Regulatory requirements. Vehicle and plant maintenance activities will be undertaken in suitable areas with hardstand to minimise risk of contaminants from incidental spills or leaks from entering aquifers via infiltration or surface runoff. Refuelling will occur within the construction footprint, at a minimum of 50 m from surface water bodies and other sensitive receptors. Refuelling locations will be equipped with onsite chemical and hydrocarbon absorbent socks/booms and spill kits. Spill kits will be available at all work fronts and laydown areas in the event of a spill or leak. All vehicles and machinery will have dedicated spill kits.

Delivery phase	Potential impacts	Mitigation measures
Construction	Water quality	Chemical and dangerous goods storage areas will be located in appropriately designed facilities, such as bunded areas, sealed or lined surfaces, hardstand areas, or storage within containers. Storage of chemicals, oils, fluids and other hazardous substances will be in accordance with the appropriate safety data sheets and relevant Australian Standards. These measures would minimise the risk of contaminants from incidental spills or leaks from entering aquifers via infiltration or surface runoff. Laydown areas and storage areas will be located to minimise potential impacts on creeks, rivers, and/or sensitive receptors such as existing groundwater bores or known GDEs. Drilling and excavation activities during construction will make use of drilling fluids and chemicals that are environmentally neutral and biodegradable, where practical. Mobile plant, drill rigs and equipment will be maintained in accordance with manufacturer requirements and inspected frequently to minimise breakdowns and decrease the risk of contamination. Identification of contaminated, hazardous, or potentially contaminated material onsite (i.e. soil, ballast) will be subject to a risk assessment and managed in accordance with relevant applicable legislation and regulations (e.g. potential asbestos found in soil is to be managed and disposed of at a site authorised to accept asbestos waste as regulated by area). Fill material will be clean, certified weed- and contaminant- free, and be required to comply with regulatory guidelines for the intended use. All excavated material that is suspected to contain sulfides should be stockpiled, lined and covered, and managed to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse are preferred to offsite disposal. A case-by-case assessment of the suitability of material for treatment and reuse will be required. The reuse or retention of contaminated or potentially contaminated material on site (i.e. soil, ballast) will be subject to a risk assessment and/or occur as per the relevant components of the CEMP. Groundwater quality monitoring ongoing as outlined in the CEMP or construction phase GMMP.
Operation	Water resources	Groundwater levels for bores will be monitored for variation from the baseline levels established prior to the operation phase.
	Water quality	Operator will notify their employees about the storage, handling, or transport of hazardous substances or dangerous goods. Operator will ensure appropriate controls are in place to prevent environmental incidents including leaks/spills from refuelling activities and locomotive operations and to protect the environment in the event that incident occur. In the event of a spill, all necessary actions will be taken to contain the spill. The supervisor or person in charge of the work activity must be notified immediately. The matter will be recorded on the reportable environmental incident checklist and, in the case of a major spill or incident, the emergency management procedure (RLS-PR-044) will be followed. Operation stage GMMP implemented and adhered to.

14.8.3 Groundwater management and monitoring program

The GMMP provides an ongoing assessment of the potential impacts identified in Section 14.7. The GMMP incorporates principles of performance assessment and adaptive management, a structured, iterative process of decision making. The GMMP will be assessed and updated after each phase of works (pre-construction/baseline, construction, and operation) such that each subsequent phase's GMMP is based on the outcomes of the previous phase.

The indicative pre-construction/baseline GMMP's primary objective is to develop a robust baseline dataset for all subsequent monitoring to be assessed against for impact identification. This dataset will also inform the proposal-specific WQO trigger values. The pre-construction/baseline GMMP will be developed and implemented during the detailed design stage to inform proposal-design aspects and ensure a suitable groundwater baseline dataset is established before starting any works.

The baseline/pre-construction dataset will be the reference dataset for future groundwater monitoring and, as such, may be supplemented with existing groundwater data inclusive of, but not limited to, representative data from local governments and recent studies. The baseline dataset will be compiled and the construction GMMP developed before the start of the construction phase of the proposal.

Subsequent groundwater monitoring during the construction phase, the construction GMMP, will be developed as a risk-based approach. Groundwater monitoring during construction will be aquifer, construction task, residual significance, and WQO-dependent. Monitoring will be localised to the area of the construction task identified to have a potential impact on groundwater quality and/or levels, as identified in Section 14.7 and their respective residual significance (refer Section 14.9.3). The localised task and risk-based monitoring will be performed at locations (distance and depth/aquifer) up- and down-gradient of the site where construction work is taking place. For example, where construction tasks are surficial in nature, no monitoring of Surat Basin aquifers would be warranted; however, surficial construction tasks may require TDS and pH monitoring within the alluvial aquifers to ensure the baseline levels are not impacted as a result of local works (task-specific monitoring).

The operation-phase GMMP will be based on the outcomes of the construction phase and will generally be warranted when a spill/incident occurs or a request for monitoring is made (e.g. from NSW EPA). These results will be assessed against the construction GMMP and baseline dataset, as appropriate.

The surface water monitoring program for the proposal will be used to inform and complement the groundwater monitoring program. For example, in the instance a surface water sample, in an area of known hydraulic connectivity with the alluvial aquifers, returns an elevated result during construction phase, this may trigger a groundwater sample to be procured from the local alluvial aquifer to inform of any impacts. However, if surface water quality results are within/below acceptable values, sampling of the alluvial aquifers in this area may not be warranted, construction task, WQO, and residual significance dependent.

An indicative network of monitoring bores in proximity to cuts are summarised in Table 14.22. The indicative network is subject to landowner negotiations and access and will be refined during the detailed design phase. If bores specified in Table 14.22 cannot be accessed, or are unsuitable for monitoring for other reasons, an alternative existing bore may be nominated. In the absence of a suitable alternative existing bore, dedicated environmental monitoring bores may be installed. These environmental wells would be sited in locations to provide adequate coverage up and down hydraulic gradient in areas of potential groundwater impact.

The pre-construction (baseline) GMMP is discussed in the following subsections. The construction-phase GMMP will be developed before construction tasks are identified to potentially impact on groundwater resources that have an elevated residual significance or a WQO trigger.

TABLE 14.22 INDICATIVE PRE-CONSTRUCTION (BASELINE) GROUNDWATER MANAGEMENT AND MONITORING PLAN BORE MONITORING NETWORK FOR THE PROPOSAL

Bore ID	Latitude (GDA94)	Longitude (GDA94)	Bridge ID or chainage	Aquifer	Screen interval (mbgl)	Monitoring type	Comments
GW018995	-28.8582	150.4047	Ch 7 km	Kumbarilla Beds	222.2 to 232.6	Water levels	Monitoring of deeper units in Kumbarilla Beds. Located between 270-BR02 and 270-BR03
BH2202	-28.8483	150.4042	270-BR2	Kumbarilla Beds	8.5 to 17.5	Water levels and quality	Monitoring potential impacts relating to bridge construction
BH2204	-28.7447	150.4167	270-BR04	Wallumbilla (inferred)	8.5 to 20.5		
BH2206	-28.7056	150.4153	270-BR06	Alluvium	8.7 to 14.7		
BH2212	-28.6669	150.4526	270-BR10	Alluvium	11.2 to 23.2		
BH2213	-28.6645	150.4533	270-BR10	Alluvium	13.5 to 19.5		
BH2217	-28.6459	150.4590	270-BR12	Alluvium	9.2 to 15.2		
GW036693	-28.6927	150.4145	Ch 25.5 km	Alluvium	14.0 to16.0	Water levels and quality	Monitoring of background water levels (not proximal to bridges). Downgradient of 270-BR06. WaterNSW monitored bore 1987 to 2015
GW036684	-28.6660	150.4124	2.8 km north of Ch 25 km	Alluvium		Water levels and quality	Down gradient monitoring of alluvium
Bore X	-28.6637	150.4391	1.2 km west Ch 30 km	Alluvium	NA—total depth 20 m	Water levels and quality	Down gradient monitoring of alluvium

14.8.3.1 Groundwater level monitoring

Groundwater levels for bores within the indicative monitoring network are to be monitored using automated pressure transducers (groundwater level loggers) to record measurements at least every 12 hours. The pre-construction groundwater level dataset will form the basis from which potential impacts can be assessed during subsequent phases of the proposal.

Manual water level measurements are proposed to be collected bimonthly during establishment of the baseline/pre-construction groundwater dataset to allow for a quality control check against the pressure transducers. Pressure transducer data will be downloaded on a bimonthly basis, during this program, to coincide with manual water level measurements and groundwater quality monitoring (discussed in Section 14.8.3.2. The baseline/pre-construction groundwater monitoring program will be continuously ongoing to account for natural (seasonal) and anthropogenic fluctuations of groundwater levels prior to construction. This is pertinent for the alluvial aquifers as the water levels in these sediments are key to the design, construction and operation of the proposal. Alluvial aquifers are the most likely to vary over time due to rainfall, drought, local groundwater abstraction, etc., and will allow for identification of non-proposal related influences on groundwater levels. For example, dewatering/pumping for construction works/water supply being undertaken for the Newell Highway Upgrade project may create an area of influence measurable in proximity to the proposal with potential to impact on groundwater resources and/or landowner bores. This information is important to capture to ensure discernibility between the impacts of the proposal and those from other influences.

The baseline monitoring program will be completed in enough time before the start of construction works to allow for assessment of the data, including trends; the construction-phase GMMP will also be developed at this time. Regular groundwater level measurements are to remain ongoing between proposal phases.

After completion of the baseline monitoring program, and with consideration of the final detailed design, the frequency and location of level measurements will be reviewed and amended for suitability to achieve the objectives of the groundwater monitoring program for the construction stage of the proposal. The shallow aquifer data will be considered together with regular surface water level monitoring data to inform the local hydraulic connectivity between surface water and shallow groundwater in the proposal footprint. This will inform the construction-phase GMMP's task-based, WQO-specific, residual significance score approach.

14.8.3.2 Groundwater quality monitoring

The pre-construction groundwater monitoring program is to include the indicative bores in Table 14.22, at a minimum, to characterise the local groundwater quality prior to construction activities. The quality data collected during the pre-construction program will be used to assess potential impacts of the proposal on local groundwater resources and on proposal-specific WQOs through all stages of the proposal. Groundwater quality samples are to be collected for field and laboratory analyses on a bimonthly basis (to coincide with the groundwater level pre-construction program).

The baseline groundwater quality program will be continuously ongoing to account for and allow characterisation of natural (seasonal) and/or anthropogenic variation before the start of construction activities. This is especially applicable to the shallow aquifers hydraulically connected to surface water, as after the dry season (negligible recharge) the first-flush/high-flow event that recharges these sediments can result in markedly different quality from data collected before, within, and after the wet season. In addition, the baseline quality dataset will indicate the potential for ARD prior to construction works and inform the suitability of local groundwater suitability for construction water purposes.

Field parameters to be collected during sampling include pH, electrical conductance (EC), temperature, redox potential (Eh), and dissolved oxygen (DO). The following analytical suite is suggested for laboratory analyses for the pre-construction groundwater quality dataset and is considered sufficient to identify potential ARD conditions and suitability of groundwater for construction water purposes (if warranted):

- pH, EC and TDS
- Major anions (HCO_{3-}, Cl^{-}, $SO4^{2-}$)
- Major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, and Si)
- Dissolved and total metals (Al, As, B, Cd, Cr, Cu, Mn, Pb, Ni, Se, Mo, Ag, Zn, Fe, and Hg)
- Nutrients (ammonia, nitrite, nitrate, total nitrogen, total phosphorus).

The pre-construction monitoring program will be completed in sufficient time before the start of construction works to allow for assessment of the data, including trends; this data will be used to define proposal-specific WQOs for those identified to be currently exceeded (refer Section 14.4.9.3). The construction-phase GMMP will also be developed at this time. Regular groundwater quality monitoring events are to remain ongoing between proposal phases.

After completion of baseline monitoring program, and with consideration of the final detailed design, the frequency and location of groundwater quality sample events will be reviewed and amended for suitability, to achieve the objectives of the groundwater monitoring program for the construction stage of the proposal. The shallow aquifer data will be complemented and considered together with regular surface water quality monitoring data to inform the local hydraulic connectivity between surface water and shallow groundwater in the proposal footprint. This will inform the construction-stage GMMP's task-based, WQO-specific, residual significance score approach.

Any WQOs derived for the proposal will be developed in reference to the ANZ Guidelines and the relevant parameters from the Border Rivers (NSW) Water Quality and River Flow Objectives discussed in Appendix N: Groundwater Technical Report.

Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines such as *Groundwater Sampling and Analysis—A Field Guide* (Geoscience Australia, 2009) unless an updated version is available prior to commencement of the baseline monitoring program.

14.8.3.3 Data management and reporting

Appropriate data and reporting will be implemented for the pre-construction GMMP, to include:

- All groundwater data to be validated with suitable QA/QC protocols applied
- Monitoring data will be reviewed on a quarterly basis, initially, to identify trends and compare to WQOs
- Reporting will be completed on an annual basis, at a minimum, through the pre-construction stage and present the assessment of water levels and water-quality trends, including hydrographs and hydrochemical plots. The annual assessment will inform the location, frequency of monitoring, and analytical suites to be incorporated into the construction GMMP to ensure the objectives of the monitoring plans for the relevant stage of the proposal are achieved.

14.9 Impact assessment

Potential impacts to groundwater values associated with the proposal in the construction and operation phases are outlined in Section 14.7. These impacts have been subjected to significance assessment as described in the methodology in Section 14.3.2 and Chapter 10: Assessment Methodology.

The initial significance assessment is based on the assumption that the design considerations (or initial mitigations) factored into the reference design phase (refer Table 14.20) have been implemented.

Additional mitigation measures, including those listed in relevant subplans (e.g. the GMMP), were then applied as appropriate to the phase of the proposal to reduce the level of potential impact, and are detailed in Table 14.21. The residual significance of the potential impacts was then reassessed after mitigation measures were applied.

The pre-mitigated significances were compared to the residual significance for each potential impact on groundwater values to assess the effectiveness of the mitigation measures (refer Table 14.23).

14.9.1 Temporary impacts

Most potential impacts related to groundwater are considered temporary and primarily associated with the construction phase of the proposal. The likelihood of a material impact on current groundwater conditions and users is low.

Final construction design, engineering controls and monitoring are generally considered to be adequate to mitigate potential impacts to groundwater. In the few locations where construction activities have the potential to intersect shallow groundwater, construction techniques have been identified for the proposal so that any impacts are mitigated and managed through the adopted engineering controls. Any remaining impacts may be managed through consultation with impacted landowners and implementation of suitable water source alternatives or compensation.

14.9.2 Long-term impacts

Beyond the construction stage of the proposal, the potential long-term impacts on groundwater are from:

- Ongoing operation of the proposal where potential impacts are likely to be surficial in nature and, through standard rail practices and procedures, not considered to impact on the shallow alluvial aquifer or the sedimentary aquifers
- Changes to groundwater levels and flow due to embankment loading and ongoing passive dewatering or drainage
- Long-term discharge and/or management of passive dewatering volumes to potential sensitive receptors, in terms of volume above baseline conditions or salinity issues
- Possible restricted access to pre-existing landowner bores.

The final construction designs, engineering controls, and monitoring are generally considered sufficient to mitigate potential impacts to groundwater environmental values. The remainder may be managed through consultation with impacted landowners and implementation of suitable water source alternatives or compensation.

14.9.3 Significance assessment

A summary of the significance assessment with respect to the proposal on groundwater resources is provided in Table 14.23.

TABLE 14.23 SIGNIFICANCE ASSESSMENT SUMMARY FOR GROUNDWATER

Potential impact	Phase	Initial significance[1] Sensitivity	Magnitude	Significance	Proposed additional mitigation measures[2]	Residual significance[3] Magnitude	Significance
Loss, damage, or restricted access to existing landowner bores	Construction	Moderate	Moderate	Moderate	Early works Confirm (i.e. physical survey/ground truth) the location of registered bores that may be lost due to construction or operation of the proposal and engage with the licensed users to complete a bore assessment to determine mitigation strategy (for example replacement of water supply, if required). Undertake bore census/survey to identify unregistered bores with potential to be impact by the proposal. Construction Implementation and adherence to the CEMP (and GMMP) for make-good arrangements with the owners of the groundwater bores (registered and unregistered), as necessary.	Low	Low
	Operations		Moderate	Moderate			
Altered groundwater levels (increase or decrease) affecting groundwater users and GDEs (incl. impacts due to embankments and seepage to cuts)	Construction	Moderate	High	Moderate (as likely to be temporary)	Design Additional investigations and assessment of potential drainage/dewatering impacts associated with cut sections to further refine current understanding and inform detailed design. Assessment of sizing for longitudinal drainage for permanent (passive) drainage features. Define requirements for construction water (volumes, quality, demand curves, approvals requirements and lead times), storage locations along the construction footprint e.g. water used for dust suppression will not result in adverse environmental or health impacts.	Moderate	Moderate (temporary)
	Operations		Low	Low	Early works Continue collection of groundwater baseline data (levels and quality) to ensure robust dataset to be incorporated into the GMMP, discussed further in Section 14.8.3. Impacts associated with dewatering (i.e. water table lowering) and environmental management requirements during construction are identified through appropriate baseline groundwater monitoring, modelling and analysis.	Low	Low

Potential impact	Phase	Initial significance[1]			Proposed additional mitigation measures[2]	Residual significance[3]	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Altered groundwater levels (increase or decrease) affecting groundwater users and GDEs (incl. impacts due to embankments and seepage to cuts)	Operations	Moderate			Construction/operation Implementation and adherence to the CEMP or OEMP and GMMP with appropriate groundwater level and quality monitoring criterion based on the baseline groundwater monitoring, modelling, analysis and regulatory requirements and make-good arrangements with the landowners (as necessary).	Low	Low
Subsidence/ consolidation due to groundwater extraction and/or loading	Construction	Moderate	Moderate	Moderate	Design Additional investigations and assessment of potential drainage/dewatering impacts associated with cut sections and areas with compressible alluvium to further refine current understanding and inform detailed designs. Early works	Low	Low
	Operations		Low	Low	Continue collection of groundwater baseline data (levels and quality) to ensure robust dataset to be incorporated into the GMMP, discussed further in Section 14.8.3. Minimise the need to abstract groundwater for construction water by considering alternative sources. Approval requirements to be considered to assist with water supply planning for embankments and cuts.	Low	Low
					Construction/operation Implementation and adherence to the CEMP or OEMP and GMMP with appropriate groundwater level and quality monitoring criterion based on the baseline groundwater monitoring, analysis and regulatory requirements and make-good arrangements with the landowners (as necessary).	Low	Low

		Initial significance[1]				Residual significance[3]	
Potential impact	Phase	Sensitivity	Magnitude	Significance	Proposed additional mitigation measures[2]	Magnitude	Significance
Altered groundwater flow regime	Construction	Moderate	Moderate	Low	Design Detailed design considerations that minimise intersections of the water table that could perturb groundwater flow and designed with adequate spacing between structures that intersect groundwater (i.e. pilings).	Low	Low
	Operations		Low	Low	Early works Continue collection of groundwater baseline data (levels and quality) to ensure robust dataset to be incorporated into the GMMP, discussed further in Section 14.8.3.	Low	Low
					Construction/operation Implementation and adherence to the CEMP or OEMP and GMMP mitigation measures during all phases of the proposal.	Low	Low
Contamination or altered water quality impacting vulnerable groundwater resources (spills or induced flow, borehole intersections Upwards leakage along pile/soil interface)	Construction	Moderate	High	High	Design Ensure vehicle/locomotive maintenance and refuel areas are located on hardstand and in areas away from surface water features, potential GDEs, and groundwater users. Engineering design considerations for vulnerable areas along the rail alignment (i.e. shallow groundwater table).	Moderate	Moderate
	Operations	Moderate	Low	Low	Further assessment of borrow pit locations for potential ARD material and suitability for construction purposes. Early works Identification of contaminated, hazardous or potentially contaminated material onsite (i.e. soil, ballast) will be subject to a risk assessment and managed in accordance with any relevant applicable legislation and regulations. The reuse or retention of contaminated or potentially contaminated material onsite (i.e. soil, ballast) will be managed by a suitably qualified person where required.		

		Initial significance[1]				Residual significance[3]	
Potential impact	Phase	Sensitivity	Magnitude	Significance	Proposed additional mitigation measures[2]	Magnitude	Significance
Contamination or altered water quality impacting vulnerable groundwater resources (spills or induced flow, borehole intersections Upwards leakage along pile/soil interface)	Construction	Moderate	High	High	Construction/operation Implementation and adherence to the CEMP or OEMP and GMMP mitigation measures. This includes spill kits on all vehicles, training of personnel in response management to contamination, strict heavy vehicle and drill rig maintenance practices. Adherence to groundwater monitoring and management (refer Section 14.8.3).	Low	Low
	Operations	Moderate	Low	Low		Low	Low
Vegetation removal and surface alteration affecting recharge/discharge, increasing associated salinity risks	Construction	Moderate	Moderate	Moderate	Construction/operation Where practical, vegetation clearing and ground-disturbing works will be staged sequentially across the proposal to minimise exposed areas. Adherence to the CEMP and/or OEMP with appropriate groundwater quality monitoring criterion based on the baseline groundwater monitoring and analysis (i.e. groundwater levels and salinity).	Low	Low
	Operations		Low	Low		Low	Low
						Low	Low

Table notes:
1. Includes implementation of initial mitigations specified in Table 14.20
2. Additional mitigations and controls, as identified in Table 14.21
3. Assessment of residual significance once the initial and additional mitigation measures have been applied.

14.10 Conclusions

This chapter has been prepared to evaluate potential impacts of the proposal on groundwater resources to be included in the EIS submission. This assessment fulfils the requirements of the NSW Department of Planning and Environment SEARs pertaining to water quality and hydrology.

The proposal will comprise approximately 30 km of new track between the town of North Star and the NSW/QLD border. The proposal is located within the NSW Border Rivers Catchment, where the alignment is oriented approximately south to north and is proposed to cross four ephemeral creeks and the perennial Macintyre River at the northern end of the alignment at the NSW/QLD border. Key groundwater management units, with respect to NSW groundwater management programs, include the NSW Border Rivers Unregulated and Alluvial Water Source and the NSW Great Artesian Basin Groundwater Source.

The proposal area is underlain by Cenozoic alluvium that unconformably overlies westward, gently dipping Cretaceous to Jurassic strata of the Surat Basin. The geology and hydrogeology for the proposal was evaluated using publicly available datasets and site-specific investigations (boreholes and monitoring wells) undertaken from July through October 2018. From approximately Ch 20 km to Ch 30 km, the proposal area is characterised by Quaternary alluvial sediments with typical thickness ranging from 20 to 60 m. The alluvium is associated with Cenozoic creek, river and lacustrine depositional events of the Border Rivers System; less extensive alluvial deposits are associated with Forest Creek, Mobbindry Creek and Back Creek. Alluvial sediments south of Ch 20 km are generally thin and overlie weathered strata of the geologic Surat Basin sediments inclusive of the Wallumbilla Formation and/or Kumbarilla Beds, encountered at depths of 5 to 10 mbgl, between Ch 0 km to Ch 20 km.

There are two main aquifers of relevance to the proposal with respect to the groundwater impact assessment:

- Cenozoic alluvium deposits associated with the Border Rivers Alluvium and other drainage systems crossed by the alignment (i.e. Macintyre River, Whalan Creek and Mobbindry Creek). This shallow aquifer system is considered sensitive to potential groundwater-affecting activities associated with the proposal.
- Jurassic to Cretaceous sedimentary aquifers of the Surat Basin, which form part of the GAB (Kumbarilla Beds and the Walloon Coal Measures).

The primary water-bearing zone in the Cenozoic alluvium is characterised by sand and sandy gravels and is overlain by a less permeable fine-grained unit comprised of clay, silt and clayey sands that may result in localised semi-confined conditions. Groundwater flow in the alluvium is inferred to mimic topography and is considered to be limited in lateral and vertical extent by the distribution of the alluvial sediments in the area. Local flow patterns of this aquifer are inferred to be towards the perennial Macintyre River, particularly between Ch 20 km to Ch 30 km.

Recharge to the alluvial aquifer is interpreted to result from stream losses from the Macintyre River and the ephemeral minor creeks/tributaries and, to a lesser extent, infiltration from rainfall and irrigation, and upward leakage from the underlying Surat Basin sediments. Groundwater levels for the alluvium are typically 7 to 20 mbgl; long-term seasonal variations are considered to typically be less than 2 m and are resultant from large rainfall and surface-water flow events. Water quality in the Cenozoic alluvium is generally good and considered suitable for stock, irrigation and drinking water, to an extent, as salinity and TDS concentrations are reported to be below 2,000 µS/cm and 1,000 mg/L, respectively. Registered groundwater bores using this aquifer are reported to primarily be located between Ch 20 km to Ch 30 km.

The Kumbarilla Beds, which underlie the alluvial sediments, form an important aquifer in the proposal area and represent the main fractured rock aquifer intersected by registered bores. Sandstone is the dominant lithology within the screened intervals and shales typically overlie these water-bearing zones; it is considered these shales may contribute to localised and potentially regional semi-confined to confined groundwater conditions. Groundwater in this aquifer is generally considered to flow northwards, per the hydraulic gradients evident in the reported potentiometric surfaces for the Kumbarilla Beds. Groundwater levels typically range from 4–36 mbgl, with water levels typically reported to be higher than the initial water strike observed during drilling, which supports the confined nature of this aquifer. An upward vertical hydraulic gradient between the Kumbarilla Beds and the overlying alluvium is evident, but aquifer interaction is likely to be limited due to the low permeability of the upper Surat Basin strata. Groundwater quality in the Kumbarilla Beds is generally suitable for stock watering and domestic purposes; however, weathered shales are recognised to overlie the sandstones that dominate this unit. Shallow bores constructed within these weathered upper shales report poor quality with salinity over 10,000 µS/cm and, thus, not suitable for stock watering or domestic uses.

The Walloon Coal Measures of the Surat Basin underlie the Kumbarilla Beds at a depth typically greater than 200 mbgl; as a result, there is a limited number of bores in the proposal area reported to intersect and/or use this aquifer. Recharge of the Kumbarilla Beds and the Walloon Coal Measures is influenced by recharge from the GAB intake beds, where the units crop out and/or subcrop on the western slopes of the Great Dividing Range.

The primary groundwater environmental values identified for the proposal include use for stock water, domestic use and irrigation from the alluvium, Kumbarilla Beds, and Walloon Coal Measures. The alluvium is also considered suitable for drinking water based on nearby water quality in Queensland. The Macintyre River, which is hydraulically connected to the alluvium, has been identified as the primary waterway with habitat that could support six threatened aquatic species and, as such, aquatic GDEs of the Macintyre River is considered a groundwater environmental value for the proposal.

Potential impacts of the proposal on the identified groundwater resources were evaluated in terms of possible impacts from the alignment on groundwater levels, groundwater flow, and water quality. The potential impacts are considered to be minimal given that the depths of the majority of structures along the alignment are not expected to intersect the alluvium groundwater. An exception is piling works for bridge foundations in 11 locations (Ch 5.7 km and Ch 32 km), which may intersect the alluvial water table; however, the piling techniques adopted for the proposal (cast-in-place) are considered suitable to limit any interaction with the groundwater of this aquifer.

A significance assessment for all identified potential impacts of the proposal on these groundwater resources was undertaken; overall, impacts from the proposal on groundwater resources are considered to be low if the recommended mitigation measures are adopted. Potential moderate impacts from construction works, which will be temporary, may include possible altered groundwater levels (from abstraction to supply construction water or from temporary dewatering) and reduction in groundwater; however, mitigation measures have been developed to manage these potential impacts.

A GMMP is outlined in Section 14.8.3 to inform baseline groundwater conditions and provide an ongoing assessment of the potential impacts of the construction and operation of the proposal on the identified groundwater environmental values. The program includes an indicative monitoring network for periodic water level and groundwater quality monitoring. Selected wells will be equipped with automated pressure transducers that record water levels. The proposed groundwater monitoring program is recommended to be reviewed annually to refine the well network and sampling frequencies.

The proposal is in line with the desired performance outcomes detailed in the SEARs and meets relevant guidelines.